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INDIVIDUALIZING INSTRUCTION FOR VARYING LEVELS OF KNOWLEDGE.
FINAL REPORT.

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THE HYPOTHESIS FOR TWO EXPERIMENTS WAS THAT INDIVIDUALIZED INSTRUCTION EFFECTIVENESS IS A POSITIVE FUNCTION OF THE MANNER IN WHICH A LESSON IDENTIFIES AND REMEDIES TYPES OF ERRORS. PAIRS OF GRADE EIGHT AND NINE STUDENTS, MATCHED FOR INTELLIGENCE QUOTIENT, AND RANDOMLY DIVIDED AS EXPERIMENTAL AND YOKED CONTROL SUBJECTS, WERE EXPOSED TO TWO PROGRAMED LESSON FORMATS ON HUMAN VISION. SELF-TEST ITEMS FOR THE INCISIVE FORMAT (I) DISTINGUISED ERRORS OF MEMORY AND OF UNDERSTANDING, WHEREAS ITEMS IN THE CONFOUNDED FORMAT (C) GAVE COMPLEX QUESTIONS AND REMEDIAL FEEDBACK. ANALYSIS OF VARIANCE WAS USED FOR A CRITERION OF LESSON MASTERY. NO SIGNIFICANT DIFFERENCES WERE FOUND FOR LEARNING TIME OR ERRORS IN EXPERIMENT I, NOR WAS THERE TRANSFER OF TRAINING. TWO EXPERIMENT II GROUPS STUDIED BOTH FORMATS IN REVERSE ORDERS. THE C-I GROUP REACHED CRITERION PERFORMANCE IN LESS LEARNING TIME AND WITH FEWER ERRORS, AND SHOWED MORE TRANSFER OF TRAINING THAN THE I-C GROUP. CONCLUSION WAS THAT C-I INDIVIDUALIZED INSTRUCTION IS BEST, WITH INCISIVE ITEMS MOST APPLICABLE TO LATER LEARNING STAGES WHERE INDIVIDUAL DIFFERENCES ARE MAXIMAL. THE DOCUMENT INCLUDES EXPERIMENTAL MATERIALS, AND A REPORT OF TWO EXPERIMENTS, "LETTER-NAMING TIME AS A FUNCTION OF SET FAMILIARITY AND SYMBOL DISTINCTIVENESS." (LH)

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Individualizing Instruction for Varying Levels of Knowledge

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Individualizing Instruction for Varying Levels of Knowledge

The purpose of the present research was to assess the effectiveness of individualized instruction as a function of the incisiveness with which the individuals in question are distinguished in terms of their respective ignorance.

Most forms of instruction, as they reduce ignorance, simultaneously increase individual differences in ignorance, for what one student learns another fails to learn and vice versa. As instruction progresses, the ignorance students share in common progressively diminishes. And the greater the differences among the students initially, the more pronounced the effect is certain to be. The resulting individualized ignorance appears to call for an equally individualized mode of instruction: one which addresses itself directly to the idiosyncratic ignorance of each individual student. In any event, the proposition that individualized instruction is the proper answer to individualized ignorance serves today as the basis of a growing interest in computerized instruction (Coulson, 4 ; Margulies & Eigen, 14 ; and Suppes, 21). However, there is a paucity of information as to the factors which contribute either to the effectiveness or the ineffectiveness of individualized instruction. And, until the principle factors are identified and their effects assessed, the development of costly computer-based instructional systems appears premature. The present research was designed to examine one such potentially potent factor: the incisiveness with which individualized ignorance is assessed.

Any and all forms of individualized instruction presuppose the possibility of distinguishing individuals in terms of their respective ignorance and of identifying and implementing the proper mode of remedial instruction for each. Individualization of instruction is not an all or nothing affair but may be said to vary in direct proportion to the number of different types of ignorance a method of instruction is able to identify and uniquely remedy. Distinguishing students who are knowledgeable from those who are ignorant of a particular bit of information must be viewed only as a token first step towards the individualization of instruction. If a student is to receive the mode of remedial instruction he needs, not only his ignorance but the nature of his ignorance must be taken into consideration. For instance, if a student's ignorance belies a failure to comprehend the lesson, he needs, presumably, remedial explanation, not drill. Or, conversely, if his memory is faulty, he needs drill rather than explanation.

Previous studies of individualized instruction have typically failed to assess the nature of a student's ignorance, and, therefore, forfeited the opportunity of selecting and instrumenting an optimal mode of remedial instruction for a given state of ignorance. It is not particularly surprising, therefore, that these studies typically have found little advantage accruing to individualized instruction.

Another shortcomming of these studies is a methodological one involving the choice of dependent variable. One would expect individualized instruction to be particularly effective only in the latter stages of learning when each student is approaching complete mastery of a lesson, but each in his own way. In the earlier stages of learning when all students are relatively naive, most any instruction is likely to be remedial, i.e., reduce some aspect of the students' ignorance. Therefore, terminal performance upon a criterion test appears inappropriate for comparing individualized with other forms of instruction. Whereas individualized instruction can properly be assessed only when learning approaches complete mastery, complete mastery virtually precludes the possibility of differences in criterion test performance for the instructional methods being compared. A more appropriate measure of the effectiveness of individualized instruction would be the amount of study time required to reach a predetermined criterion of lesson mastery. However, with ironic unanimity researchers seem invariably to have employed the criterion test for assessing the effectiveness of individualized instruction. Accordingly, the frequent "negative results" are not without explanation.

The studies in question appear in the literature under the rubric of programed instruction and report comparisons of branching or bypassing programs - which adapt the instructional sequence to suit the students' ignorance either by reviewing sections of the lesson on which the student is weak or by skipping sections on which he is strong - and fixed sequence or linear programs - which instruct all students alike. Of twelve studies appearing in the literature, only a few report univocal evidence for the proposition that branching, adaptive or individualized instruction is more effective than linear, fixed sequence, or regimented instruction.

Five studies have failed to find any advantage for individualized programs in terms of either criterion test performance or rate of learning (study time):

> Campbell (3) compared a bypass program with a short linear program and a long linear program and found test score and study-time means highest for the long program and lowest for the short program with the bypass program falling in between. He concluded that the method of bypassing was no more efficient than the linear methods.
>
> Glaser, Reynolds, Harakas, Holzman, and Albma (8) found that alternative "linear" routes through a "multilinear" program proved no more effective than had bypassing.
>
> Roe (16), using students in a freshman engineering course at UCLA as subjects, compared a linear program on the topic of probability with two types of branching program: backward branching (remedial loops), and forward branching (bypassing). He found only

a significant difference in learning time between the linear and the backward branching programs, the branching program taking longer.

Senter, Nieberg, Albma, and Morgan (18) converted Crowder's scrambled text "The Arithmetic of Computers" (a branching program) into two altered versions: (a) one in which branches incorporating motivational comments were deleted, and (b) one in which all branching was replaced by a linear sequence. Results showed no significant difference in amount learned or in study time.

Finally, Silberman, Melaragno, Coulson, and Estavan (20), using a computer-controlled teaching machine to teach rudimentary logic, found no significant differences between a branching and a fixed-sequence program. They used study time and aptitude as control variables in their covariance analysis of criterion-test scores.

Three studies have reported that students spend less time studying branching than linear programs without adversely effecting criterion test performance:

Beane (1), comparing linear and branching versions of a program on plane geometry found that students completed the branching version more rapidly while learning an amount equivalent to those reading the linear version.

Bibiscos (2), using subjects differing in acumen and in preknowledge of the subject matter compared linear and bypassing versions of a program on the topic of Roman numerals. Students studying the bypassing version achieved the same level of lesson mastery as the students taking the linear version, but in significantly less time.

Coulson and Silberman (6) instructed junior-college students in introductory psychology using fixed-sequence and branching versions of a program. The branching versions required less training time than the fixed sequence versions, but were not significantly different in terms of either immediate or delayed (three weeks) criterion test performance.

The findings of Beane; Bibiscos; and Coulson and Silberman, although promising, do not demonstrate univocally the presupposed advantages of individualized instruction. It is a simple matter to prepare two versions of a lesson which differ in redundancy and demonstrate that the terse version is more efficient. In fact, Pressy and Kinzer (15), and Hershberger (10) have each shown that a terse version of a lesson may be more effective as well as more efficient than a redundant version. Hershberger compared tersely and discursively-written text-book passages. Pressy and Kinzer compared an "auto-elucidative" version of a portion of Analysis of Behavior with the original linear version. It is quite possible that the subjects studying the branching programs in the Beane; Bibiscos; and Coulson and Silberman studies were able to "edit out" an unessential redundancy in the lesson, and that this, rather than individualization if instruction was responsible for the demonstrated learning efficiency of the branching versions.

There is only one study in the literature which reports results favoring individualized instruction in terms of criterion test performance:

> Coulson, Estavan, Melaragno, and Silberman (5), using the basic program on logic they had employed in their 1961 study, ferreted out a statistically significant advantage ($p < .05$, one-tailed test) for a branching as opposed to a fixed sequence program. Although the branching version also required less study time, the difference was so small as to be attributable to chance. Coulson, et.al. attributed the differences between these findings and their 1961 results to certain modifications in the branching procedures resulting in (a) "more accurate diagnosis of student needs," and (b) "more effective remedial materials for filling these needs". Diagnosis was improved by requiring the student to decide whether he wished additional instruction rather than depending solely upon error rate as a branching criterion. Remedial materials were improved by being designed to correct the specific ignorance evidenced by a previous student error,

e.g., "No, you gave the answer '∨' when you should have answered '∧'. Remember, '∧' represents 'and' while '∨' represents 'or'."

It is apparently the incisiveness rather than the voluntary nature of the branching criterion which is responsible for Coulson *et*. *al's* results, for Hartley (9), comparing voluntary versus mandatory branching, found an advantage in learning time for the mandatory procedure. Hartley attributed this to a tendency on the part of his students using the voluntary-branching procedure to browse through the novel program reading material they had already mastered. Apparently, they were using a branching criterion based upon degree of curiosity rather than degree of lesson mastery.

The principle objective of the present research was to systematically investigate the implications of the findings of Coulson *et*. *al*., namely, that the effectiveness of so-called individualized instruction is a positive function of (a) the incisiveness with which a student's ignorance is diagnosed, and (b) the appropriateness of the corresponding remedial instruction. Two experiments were conducted. (A third experiment, unrelated to the present purpose but partially supported by the present grant was reported in a previous paper and submitted as an interim report. A revised version of that paper appears in Appendix E of the present document: "Letter-Naming Time as a Function of Set Familiarity and Symbol Distinctiveness.") In each experiment junior high school students were required to learn rudimentory, functional anatomy of the human visual system. The lesson included a set of self-test items (Hershberger, 11) by which the students could assess their respective ignorance of lesson content. Three types of self-test items were used: (a) one which assessed *memory* for terminology, (b) one which assessed *understanding* of functional relationships, and (c) one which did not distinguish between errors of understanding and errors of memory but assessed both. Each self-test item was followed in the lesson by a correct answer which was either remedial or confirmatory depending upon the subject's response. The answers were of such a nature that errors of memory to type "a" questions resulted in remedial drill; misunderstandings of function evidenced by errors on type "b" questions were disabused with the aid of detailed explanations; and, errors to type "c" questions resulted in both types of remedial instruction indiscriminately.

The lesson was prepared in two parallel formats, each comprised of an illustrated text and a set of 27 self-test items. The same tersely-worded text was used in each format, and the self-test items of the two formats, although different in type, covered the same 27 units of information. The formats differed only in the type of self-test items used: one, the incisive format, incorporated both type "a" memory items and type "b", understanding items, whereas the other format, the confounded format, included only nondiscriminating, type "c" items. It was hypothesised that the incisive format would prove superior to the confounded format as a mode of individualized instruction. Two experiments were conducted to test the hypothesis.

EXPERIMENT I

Method

Subjects:

A total of 68 eighth-grade students enrolled at Northern Illinois University Junior High School during the 1966-67 academic year served as the subject pool for Experiment I. The students were combined into 34 pairs of subjects with the members within each pair matched in terms of I.Q. Each pair was then assigned to one of two equal-size groups equated for mean I.Q. Unfortunately, during the course of the experiment, which extended over a period of several weeks, 11 pairs of subjects were lost due to absences of either one or both members of a subject pair. Data is reported here for 23 pairs, 12 in one group and 11 in the other. The mean I.Q. for each of the two groups was 118 - California Test of Mental Maturity: Total Score.

Materials:

The experimental lesson, entitled "Some Functional Anatomy of Human Vision" was written by one of the authors and totals approximately 1,000 words; it includes two drawings. A copy of this basic text appears in Appendix A. This particular lesson topic was selected because it provided both an esoteric terminology and a functional system complex enough to be readily confused. Moreover, it was a topic about which the subjects were uniformly naive.

Two parallel sets of 27 self-test items each were constructed as adjuncts to the basic text. Each set was designed to assess the student's grasp of the same 27 independent items of information. One set, the Incisive Format, incorporated two types of items, one assessing and remedying errors of memory for anatomical terminology and the other assessing and remedying errors of understanding of anatomical function. The other set of self-test items, the Confounded Format, confounded these two types of errors by asking complex questions involving both memory for terminology and understanding of function. Likewise, remedial feedback for each mixed item involved both detailed explanations of function and identification of requisite terminology.

The 27 items comprising the Incisive Format (101i to 127i) appear in Appendix B. The 27 items comprising the Confounded Format (101c to 127c) appear in Appendix C. The self-test items were printed on 5 1/2 x 8 inch sheets of paper, with the question (q) on the front side and the answer (a) or remedial instruction on the back. Multiple copies of a given item were then bound together in tablet form, any page of the tablet being identical to every other page. Thus were constructed 27 tablets for each of the two formats.

Such a deck of 27 tablets was prepared for each subject pair, 11 decks of the Incisive Format and 12 decks of the Confounded Format. The tablets were passed out daily to the subjects in manila envelopes bearing the following instructions:

> "Work through the enclosed deck of tablets answering the questions on the front page of each tablet. After writing your answer, immediately tear off the first page and look on the back for the correct answer. If your answer is right, place that tablet aside on the right. If wrong, lay it to your left. When you have gone through the entire deck in this way, shuffle the pile on your left and start over, continuing this procedure as often as necessary until you have finally answered every question correctly, that is, until all the tablets are in a pile to your right. Please place the answer sheets you tear off into this envelope."

The tablets, used in this way, provided remedial drill as a result of an incorrect answer to a self-test item. On the other hand remedial answers to items 101 through 107 of both formats incorporated detailed explanations and corrective exercises. Once an erring subject had completed this remedial exercise, he was instructed to place the "tablet on the correct pile on his right," thereby precluding additional drill.

In the Incisive Format, items 101 through 107 assessed errors of understanding of function and items 108 through 127 assessed errors of memory. Thus, the appropriate type of remedial instruction for these two types of errors was provided by the instructed use of the self-test tablets: explanations for misunderstandings and drill for faulty memory.

In the Confounded Format, however, where type of error was not specifically identified it was necessary to provide both types of remedial instruction, i.e., to provide for either type of error. The above instructions to the subjects to repeat any tablets answered incorrectly provided for remedial drill. And, to disabuse the reader of any misunderstanding of anatomical function, the answer to each question in the Confounded Format included an appropriately detailed remedial explanation. (There were no such explanations in the answers to the memory items of the Incisive Format: in the Incisive Format, each answer to a pure memory item was comprised simply of the term the reader was being asked to identify. See Appendices B and C for a detailed comparison of the two formats.)

Procedure:

One of the aforementioned groups of subject-pairs (n=11) studied the lesson using the Incisive Format; the other group (n=12) used the Confounded Format. A randomly selected member of each pair was designated as the experimental subject and his partner became his yoked control. The decks of 27 tablets described above were used by the experimental subject in each subject pair.

The control subject did not get a deck of tablets. He was given only one tablet comprised of an assortment of self-test items. The daily assortment of pages in a control subject's tablet was identical to the group of pages his experimental partner had used up, the day before. The study schedules of the experimental and control subjects were staggered one day to allow time to prepare the control materials in this fashion. With this yoked procedure, the instruction of the control subjects, although not individualized to their own ignorance, was, nevertheless, identical operationally to that of their experimental partners.

The subjects studied the lesson daily for several days. In order to get as detailed a record as possible of the learning process, the student was permitted to study the basic text only once, the first day. Thereafter, he studied the lesson using the self-test tablets exclusively.

Because of practical time limitations only tablets 101 through 107 accompanied the basic text on the first study day, and only tablets 108 through 127 were used on the second day. Each day thereafter each experimental subject was assigned all the self-test tablets except those he had answered errorlessly the very previous day. In other words, each experimental subject encountered all 27 self-test items during each consecutive two-day period. The lesson was defined as mastered when he was able to answer all self-test items errorlessly on two successive days. Experimental subjects who had not met this criterion by the end of the 15th study session were arbitrarily scored as having mastered the lesson on the 15th day of study.

Once a subject reached the criterion of lesson mastery he then took, on the following day, a test of transfer of training composed of the questions comprising the alternate study format.

On the 36th calendar day following the first day of study, each subject was administered a retention test composed of the questions comprising the format he had studied.

The experiment was carried out in the standard classroom under the administration of the students' regular instructors. Four intact classes of students were used, with each experimental condition equally represented in each class. The study materials were passed out at the beginning of the class period and picked up individually as soon as each student completed his materials. When not actively participating in the experiment proper, students were busied with regular school assignments.

Results

Five measures of each subject's performance were recorded as data: (a) the number of study-days it took a subject to achieve the criterion of lesson mastery; (b) the number of minutes it took him to reach criterion; (c) the number of errors he committed in the process of reaching the criterion; (d) the number of items in the transfer test he answered correctly (out of a possible total of 27); and, (e) the number of items in the retention test he answered correctly (out of a possible total of 27).

Table 1 shows for both experimental and control subjects of each lesson format the group means on each of the dependent variables listed above.

Table 1

Group Means on the Five Dependent Variables of Experiment I

Dependent Variable	Groups			
	Incisive Format		Confounded Format	
	Exper.	Cont.	Exper.	Cont.
Number of Days to Criterion of Lesson Mastery	9	9	11.4	11.4
Number of Minutes to Criterion of Lesson Mastery	130.6	125.0	156.6	105.5
Number of Errors to Criterion of Lesson Mastery	59.4	59.7	56.7	69.6
Transfer of Training: Number Correct out of 27 possible	11.1	11.1	9.8	9.7
Retention Test: Number Correct out Of 27 possible	19.3	17.4	18.4	15.3

Days to criterion. Because the control subjects were yoked to their respective experimental partners on this variable, their mean Days to Criterion have zero degrees of freedom and are to be ignored. As for the experimental subjects, the difference between those using the Incisive and Confounded Formats is statistically insignificant (Mann-Whitney $U=40.5$, $n_1=11$, $n_2=12$; $p>.10$). The means for the Incisive and Confounded Formats were 9 and 11.5 days respectively.

Minutes to criterion. Figure 1 shows the daily mean number of minutes subjects in each experimental condition spent working through the self-test items. The times for the first and second sessions have been combined since only seven items were used the first day.

Table 2 summarizes a three-way analysis of variance of the study-time data represented in Figure 1.

Table 2

Analysis of Variance Summary of Study Time Data

Source	df	MS	F	p
Between Subjects	45			
Formats	1	321.90	2.55	>.05
Groups (Exper. vs. Control)	1	754.36	5.95	<.025
Formats x Groups	1	31.68		
Error (between subjects)	42	126.78		
Within Subjects	598			
Days	13	6,709.17	264.87	<.001
Days x Formats	13	9.29		
Days x Groups	13	106.79	4.22	<.001
Days x Formats x Groups	13	9.82		
Error (within subjects)	546	25.33		

Two main effects and one interaction are significant: Days, Groups, and Days x Groups. As can be seen in Figure 1, the subjects in all experimental conditions spent progressively less time working through the self-test items on successive days. And, the average control subject spent less time (113.9 min.) than the average experimental subject (144.2 min.) in

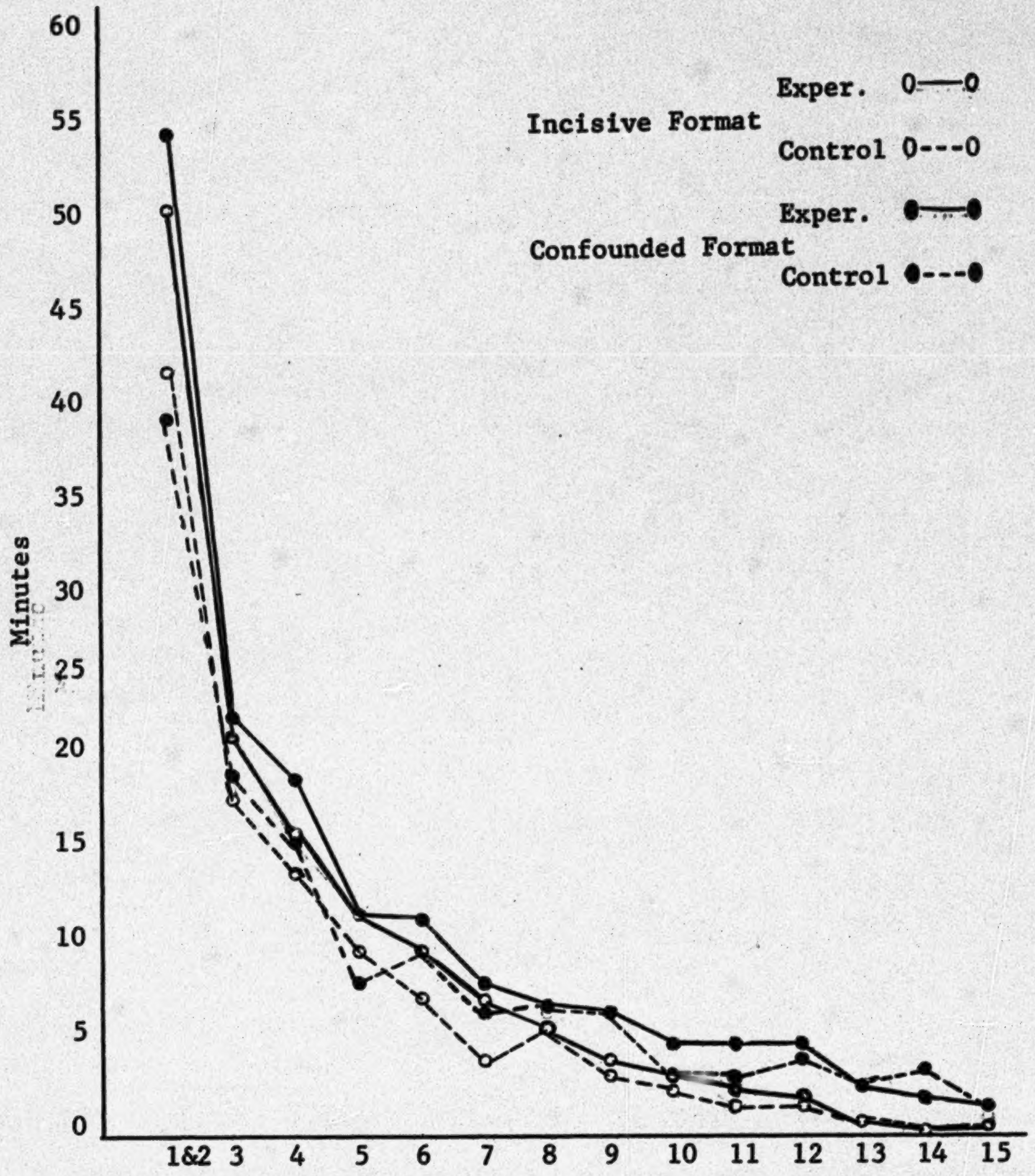

Fig. 1 Mean daily study time for each experimental condition. Days 1 and 2 have been combined.

covering the very same materials. But, as can be seen from Figure 1, this difference between experimental and control subjects varies as a function of Days, disappearing by the last day of study.

Number of errors to criterion. Figure 2 shows the daily mean number of errors committed by the subjects in each experimental condition in working through the self-test items. The errors for the first and second sessions have been combined since only seven items were used the first day.

Table 3 summarizes a three-way analysis of variance of the error data shown in Figure 2.

Table 3

Analysis of Variance Summary of Error Data

Source	df	MS	F	p
Between Subjects	45			
Formats	1	10.78		
Groups (Exper. vs. Cont.)	1	38.77		
Formats x Groups	1	32.76		
Error (between subjects)	42	65.78		
Within Subjects	598			
Days	13	1,386.05	97.61	$<.001$
Days x Formats	13	29.01	2.04	$<.05$
Days x Groups	13	27.72	1.95	$<.05$
Days x Formats x Groups	13	4.63		
Error (within subjects)	546	14.20		

Three effects are significant: Days, Days x Formats, and Days x Groups. On successive Days the subjects in all groups committed progressively fewer errors. In the early days the Incisive Format yielded more errors than the Confounded Format, but later the opposite became true. Similarly, the control subjects committed fewer errors the first day and more errors during the later days of the exercise than did their experimental counterparts.

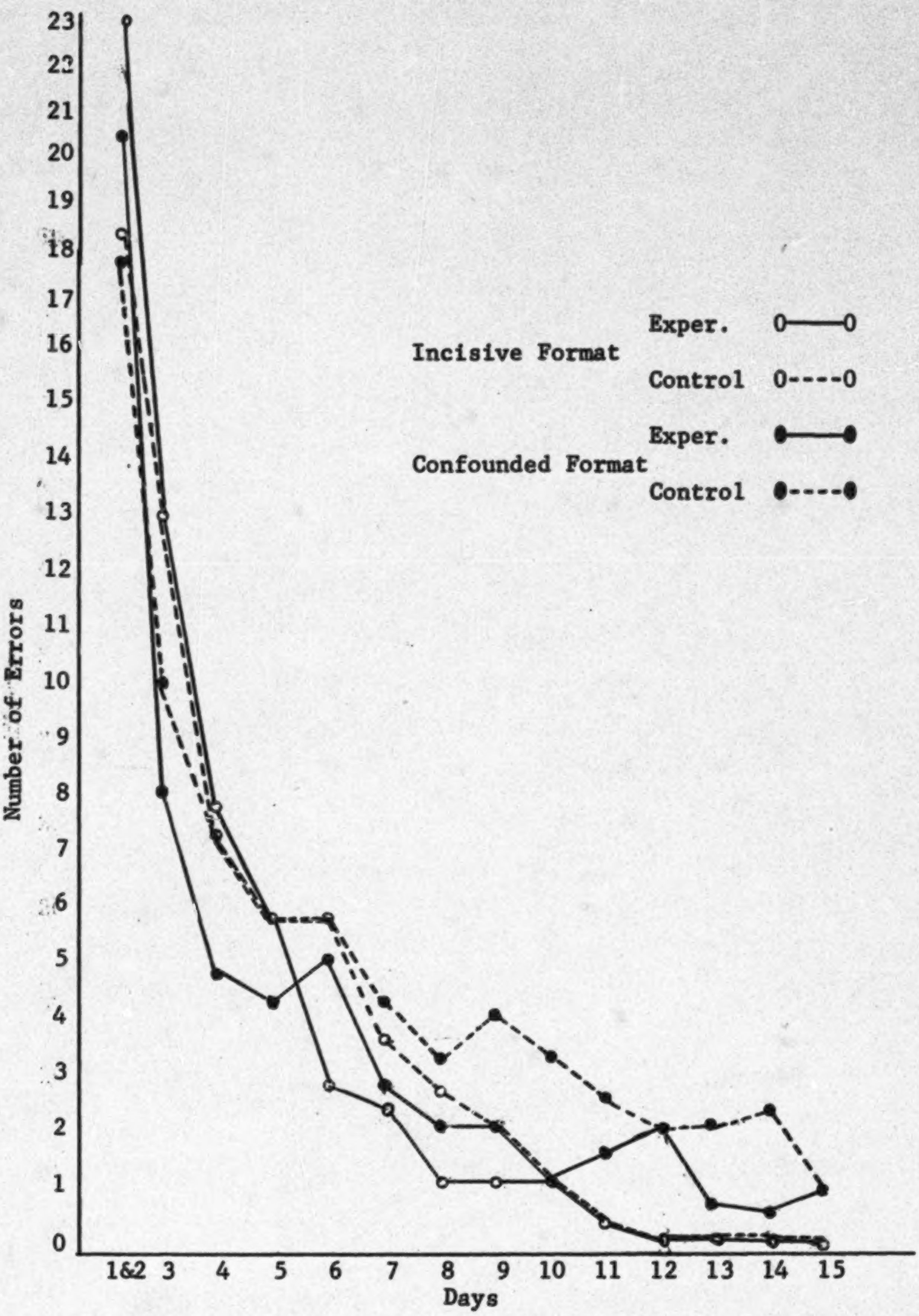

Fig. 2 Daily, mean number of errors is shown for each experimental condition. Days 1 and 2 have been combined.

Transfer of training. Table 4 summarizes a two-way analysis of variance of the transfer test data. No effects are significant.

Table 4

Analysis of Variance Summary of Transfer Test Data

Source	df	MS	F	p
Between Subjects	45			
Formats	1	9.81	-	
Groups (exper. vs. cont.)	1	1.39	-	
Formats x Groups	1	1.27	-	
Error	42	24.82		

To assess the actual amount of transfer of training evinced by the experimental subjects of each lesson format, it was necessary to determine the basal performance of untrained subjects on each set of transfer-test items. Since the transfer-test items of each format were identical to the self-test items of the alternate format, this basal performance was obtained by counting the number of self-test items each experimental subject had answered errorlessly during his first pass through the deck of 27 self-test tablets. The number of such correct responses to the Incisive Format, (the transfer-test items of the Confounded Format), ranged from 0 to 20 with a mean of 8.8. The number of correct first-pass responses to the items of the Confounded Format ranged from 3 to 21 with a mean of 9.2. These means of 8.8 and 9.2 do not differ significantly from the corresponding transfer test means of 9.8 and 11.1 respectively.

Retention test. Since there is no significant evidence of positive transfer, the assumption that the test items of the two lesson formats assess the same 27 units of information is highly questionable. Apparently, the tests assess two independent sets of information. And, since this "information" variable is completely confounded with the format variable, any comparison of retention test data across formats is at best questionable. Hence, only the experimental and control groups within each format were compared.

Using a t test for yoked samples it was found that whereas the experimental and control subjects studying the Incisive Format did not differ significantly on the retention test (t=.969, df=10, $p>.05$), the control subjects using the Confounded Format performed more poorly than their experimental counterparts (t=2.05, df=11, $p<.05$). The means for each experimental condition are shown in the last row of Table 1.

EXPERIMENT II

Method

Subjects:

A total of 63 ninth-grade students enrolled at Northern Illinois University Junior High School during the 1966-67 academic year served as subjects for Experiment II. The subjects were divided into two nearly equal-size groups matched for mean I.Q. (123 California Test of Mental Maturity: total score). Five subjects were lost due to routine absences from class, leaving two groups of 30 and 28 individuals.

Materials:

The basic materials were the same as those used in Experiment I. In addition, a four-item questionnaire assessing student opinion of the two lesson formats was constructed. A copy of the questionnaire appears in Appendix D.

Procedure:

The aforementioned group of 30 subjects, the I-C Group, studied the Incisive Format to a predetermined criterion of lesson mastery, then switched to the Confounded Format and continued studying to the same criterion with the new format. The other group, the C-I Group (n=28), followed the same procedure in reverse order.

The daily procedure was similar to that of Experiment I. As in Experiment I, the subjects read the basic text only on the first day of the exercise. Also, they were given only the first seven self-test items, (101-107) on the first day and the remaining 20 items (108-127) on the second day. From the third day on, however, the procedure for assigning self-test tablets varied somewhat from that of Experiment I. On the third day each subject got only those self-test items he had missed at least once in his first pass through the deck. On each day thereafter, he got only those items he had missed at least once the previous day. When eventually he performed errorlessly on a single day, he was given on the following day all 27 tablets. Then the procedure was repeated: each day he was again given only those items he had missed at least once the previous day until he again performed errorlessly on a single day. On the day following this second and all subsequent errorless performances, the subject was given all self-test items except those he had answered correctly on two consecutive attempts. (Proper use of the self-test tablets did not permit the subject to answer an item correctly twice in one day.) The lesson was defined as mastered when the subject had answered each of the 27 self-test items correctly on two successive attempts. When the subject had mastered one format and had switched to the alternate, the basic text was omitted and he began with all 27 tablets in the new deck.

These procedures were adopted in preference to those used in Experiment I on the grounds that they should more effectively individualize instruction, minimizing either boredom or overlearning by reducing practice of perfected responses.

The exercise was terminated after the 21st day of study. One subject in the C-I Group who had not yet reached the criterion of mastery on the second format was assigned an arbitrary score of "21 days to final criterion."

On the 53rd calendar day following the first day of the study all subjects were administered the aforementioned questionnaire and a retention test composed of the 54 questions comprising the two sets of self-test items.

The experiment was carried out in a standard classroom under the administration of the students' regular instructor. Three intact classes were used, with each of the two experimental groups represented in each. The study materials were passed out at the beginning of the class period and picked up individually as soon as each student completed his materials. When not actively participating in the experimental task, the students were allowed to busy themselves with conventional classroom activity of their own choosing, providing only that it disturbed no other students in the room. This procedure was initiated by the instructor to avoid penalizing any students who completed the experimental materials early.

Results

In addition to his responses to the aforementioned questionnaire, five objective measures of each subject's performance were recorded as data: (a) the number of study-days it took him to reach each criterion of lesson mastery; (b) the number of minutes it took him to reach each criterion; (c) the number of errors he committed in the process of reaching each criterion; (d) the number of tablets he encountered in achieving each criterion; and (e) the number of test items of each type, Incisive and Confounded, which he answered correctly in the retention test.

Table 5 shows the mean performance of each group on all five dependent variables.

Table 5

Mean Performance of Each Experimental Group on the Five Dependent Variables of Experiment II

Group	Lesson Format	
	Incisive	Confounded
Number of study-days to criterion		
I-C	7.4	6.5
C-I	7.1	5.7
Number of minutes to criterion		
I-C	71.0	56.0
C-I	74.6	45.5
Number of errors to criterion		
I-C	38.2	23.3
C-I	18.1	23.8
Number of tablets to criterion		
I-C	85.8	78.4
C-I	71.2	79.2
Number of errors on retention test		
I-C	8.2	13.3
C-I	9.3	12.0

Days to criterion. Table 6 summarizes a two-way analysis of variance of the days to criterion data.

Table 6

Analysis of Variance Summary of Days to Criterion Data

Source	df	MS	F	p
Between subjects	57			
Groups	1	8.99	8.10	< .01
Error (between subjects)	56	1.11		
Within Subjects	58			
Format	1	38.7	3.76	> .05
Format x Groups	1	-	-	
Error (within subjects)	56	10.29		

Only the main effect for Groups is significant. On the average, the I-C Group took significantly more days (7.0) than the C-I Groups (6.4) to master the two formats.

Minutes to criterion. Table 7 summarizes a two-way analysis of variance of the minutes to criterion data.

Table 7

Analysis of Variance Summary of Minutes to Criterion Data

Source	df	MS	F	p
Between Subjects	57			
Groups	1	347.55	-	
Error (between subjects)	56	426.23		
Within Subjects	58			
Format	1	13,773.24	72.35	< .001
Format x Groups	1	1,167.45	6.13	< .025
Error (within subjects)	56	190.38		

Two effects are significant, Formats, and Groups x Formats, the latter being a simple order effect, i.e., first vs. second format studied. On the average, the Incisive Format took longer to master (72.7 minutes) than the Confounded Format (50.9 minutes). And, the students spent less time studying their first format (mean time=58.3 minutes) than they did their second format (mean time=65.3 minutes).

Errors to criterion. Table 8 summarizes a two-way analysis of variance of the errors to criterion data. All three effects are significant.

Table 8

Analysis of Variance Summary of Errors to Criterion Data

Source	df	MS	F	p
Between Subjects	57			
Groups	1	2,792.67	7.26	<.025
Error (between subjects)	56	384.65		
Within Subjects	58			
Formats	1	710.07	4.98	<.05
Formats x Groups	1	4,176.28	29.32	<.001
Error (within subjects)	56	142.45		

The I-C Group made a greater number of errors on the average (30.8) than the C-I Group (21.0). The students committed more errors on the Incisive Format (mean=28.5) than on the Confounded Format (mean=23.6). And, they also made more errors on the first format they studied (mean=31) than they did on the second (mean=20.7).

Tablets to criterion. Table 9 summarizes a two-way analysis of variance of the tablets to criterion data. Two effects are significant, Groups and Formats x Groups, the latter being a simple order effect. The I-C Group used more tablets (mean=82) than the C-I Group (mean=75.2).

Table 9

Analysis of Variance Summary of Tablets to Criterion Data

Source	df	MS	F	p
Between Subjects	57			
Groups	1	1,380.48	4.27	$<.05$
Error (between subjects)	56	323.32		
Within Subjects	58			
Formats	1	-		
Formats x Groups	1	1,707.12	14.55	$<.001$
Error (within subjects)	56	117.34		

And, the students used more tablets working through the first format they studied (mean = 82.5) than they did the last (mean = 74.8).

Retention test. Table 10 summarizes a two-way analysis of variance of the retention test data. Two effects are significant, Formats and Groups x Formats, the latter being a simple order effect.

Table 10

Analysis of Variance Summary of Retention Test Data

Source	df	MS	F	p
Between Subjects	57			
Groups	1	-	-	
Error (between subjects)	56	43.89		
Within Subjects	58			
Formats	1	452.08	63.67	$< .001$
Formats x Groups	1	50.69	7.14	$< .025$
Error (within subjects)	56	7.10		

More errors were committed on the items of the Confounded Format (mean number of errors = 12.7) than the items of the Incisive Format (mean number of errors = 8.7). And, the students made fewer errors on the items from the format which they had studied first (mean = 10.1) as opposed to the one they had studied last (mean = 11.3).

Questionnaire data. The responses of the subjects to the four items of the questionnaire are summarized in Table 11.

Table 11

Questionnaire Data: Shown for Each of the Four Items Are the Relative Frequencies With Which Each Alternative Was Selected By Each of the Experimental Groups

Response Alternatives	Groups	
	I-C	C-I
1. Which type of question did you find most difficult?		
Incisive	35%	71%
Confounded	24%	18%
About equal	41%	11%
2. Which type of question was more instructive?		
Incisive	58%	47%
Confounded	7%	21%
About equal	35%	32%
3. Did you find that your studying the first format affected the difficulty of studying the second set?		
It made the second set easier.	38%	43%
It made the second set more difficult.	10%	4%
It had no effect.	52%	53%
4. On which format did you do the most guessing?		
Incisive	21%	21%
Confounded	48%	58%
About equal	31%	21%

A Chi-square test of independence was used to compare the performance of the two groups on each of the questionnaire items. The groups differed significantly only in terms of their responses to item 1, "Which type of item did you find more difficult?" The members of the C-I Group selected the "Incisive" alternative twice as frequently as the I-C Group, and the "About equal" alternative much less frequently than the I-C Group.

Disregarding the subjects who selected the "About equal" alternatives, and combining the remainder of the two experimental groups on questionnaire items 2 and 4, 79% felt the Incisive Format was more instructive and 29% said they did less guessing with the Incisive Format; both percentages are significantly different from 50%, $p < .05$.

Combining the two groups on questionnaire item 4, only 40% felt that studying the first lesson format made studying the second format easier; the remaining 60% felt that studying the first format either had no effect or a detrimental one. The proportion .4 does not differ significantly from .5 for the present sample of size $n = 58$.

The statistical analyses used herein are described in detail by Walker and Lev (22) and Linquist (13).

Discussion

The results of Experiment I failed to confirm the expectation that the experimental subjects using the Incisive Format would perform better than those using the Confounded Format. No Format, nor Format X Group effect proved to be significant. In comparison to those students studying the Confouned Format, those studying the Incisive Format took as many days and as many minutes to reach the criterion of lesson mastery, committed as many errors in the process, and demonstrated no more transfer of training. In fact there appeared to be no transfer of training from either lesson format to the other. The students studying each format performed on their respective transfer tests no better than their alternate groups had performed in their first pass through those same items encountered in the lesson. Since the two lesson formats were intended to assess the subjects' grasp of the same 27 units of information, this apparent absense of transfer of training was somewhat surprising. However, it is not uncommon in cases of demonstrated positive transfer of training for there to occur an initial but short-termed negative-transfer effect as the result of incidental situational variables (25). Such was assumed to be the case here. The nature of the student response to the items of the two formats differed, the Incisive Format calling largely for constructed responses whereas the Confouned Format required the selection of the correct member of a set of alternatives. It was supposed that this difference in response requirement or the like had a negative transfer effect which obscured any positive transfer of training. Further, since such a deleterious effect would normally diminish as the student gained experience with the new response mode, it was supposed that positive transfer of training across the two lesson formats might be evinced if subjects were to study both formats to criterion, one after the other. Positive transfer of training would show up as a reduction in time or errors required to achieve criterion on the second format studied.

Such was the purpose of Experiment II. Two matched groups of subjects studied both lesson formats, the I-C Group taking them in the order Incisive-Confounded and the C-I Group taking them in the reverse order. It was expected that the students' mastery of the second lesson format would be accelerated by their previous mastery of the first. Further, although it was recognized that the I-C Group which studied the Incisive Format first might perform more effectively than the C-I Group from having used the more individualized format during the first and presumably more difficult half of the exercise; the opposite prediction follows from the premise that individualized instruction is most crucial during the later stages of learning where individual differences in ignorance are at a maximum.

The results of Experiment II confirm the latter prediction. The C-I Group took significantly fewer days to reach the terminal criterion, committed significantly fewer errors, and used fewer tablets in the process than did the I-C Group.

Further, the transfer of training absent in Experiment I evinced itself in Experiment II in terms of a reduction, from the first to the second format, of both errors and tablets to criterion. Curiously, these reductions in errors and tablets to criterion were accompanied by an increase in study time. However, this disparity is not as paradoxical as it first appears. Judging from their responses to the questionnaire items (particularly Group C-I on item 1) it appears that the students, having mastered the first format and being somewhat knowledgeable, were inclined to spend more time thinking about their answers before responding to the questions in the second format, and that this inflated their study-time scores. (Presumably, it was because of this earnest effort that so many of the C-I Group, 71%, considered the Incisive items, more difficult than the Confounded items, i.e., they seemed more difficult because the students were trying harder.)

Although both groups increased their study-time from the first to the second format, it was principally the C-I Group which profited from this effort in terms of a reduction of errors committed and tablets used. Further, the absolute magnitude of these reductions, although substantial (e.g., the mean difference in errors to criterion on the Incisive Format for the two groups was 20.1) were not so great as to obscure a real difference in the information assessed by the self-test items of the two lesson formats.

Both of these findings have particular relevance to the issue of frame format in programmed instruction. Skinner (19) has advocated a constructed response type of frame which in practice tends to place a premium upon memory as opposed to "understanding." Pressy (15), on the other hand, has advocated multiple-choice type items designed to elucidate relationships and implications which are not readily or economically stated in textual form. Studies conducted to evaluate these two formats (constructed response versus multiple choice) as alternate modes of teaching the same lesson have yielded equivocal results (15 , 17). The present results of both experiments suggest, however, that the two formats are complementary in what they teach and that they should not be thought of as alternate methods for teaching the same materials. The present results also suggest that when both types of items are used in the same lesson, the auto e lucidative, multiple-choice type items should precede the constructed-response type items which tend to be more incisive in their assessment of errors of memory. They should come last not only because they tend to be more incisive but also because the students, being more knowledgeable by that time, tend also to be more individualized in their respective forgetfulness. Similar findings have been reported by Williams in two response mode studies (23 , 24). She found that students profited from constructed response items more when they were used to review a topic previously studied than when they were used during original learning.

Conclusion

Information which students learn from self-test items of a complex type involving both memory and understanding is markedly different from that learned from incisive items which assess either memory or understanding but not both. Apparently, the former involves primarily discrimination training and the latter primarily response training. A comprehensive program of individualized instruction should, therefore, incorporate both types. Further, the complex items should precede the incisive items inasmuch as the incisive items appear to be particularly effective only during the later stages of learning when individual differences in ignorance are at a maximum.

Inasmuch as response learning would typically be rated as propaedeutic to discrimination learning, in terms of Gagne's proposed hierarchical organization of knowledge (7), the present conclusion that discrimination training should precede response training may appear inimical to good reason. However, therein lies the potential benefit of the present research: the remission of a faulty preconception.

Summary

Two experiments were conducted to test the hypothesis that the effectiveness of individualized instruction is a positive function of the incisiveness with which a lesson format identifies and appropriately remedies various types of ignorance.

In each experiment, junior high-school students studied various formats of a lesson on the human visual system. Two formats were used, each composed of self-test items designed to cover the same 27 units of information, but differing in their degree of incisiveness. One format, the Incisive Format, was comprised of two types of items, one assessing and remedying errors of memory and the other assessing and remedying errors of understanding. The other format, the Confounded Format, was comprised wholly of complex questions and equally complex remedial feedback.

In the first experiment, 11 matched pairs of subjects used the Incisive Format and 12 matched pairs used the Confounded Format. A randomly selected member of each pair was designated as the experimental subject and the remaining member became his yoked control. The experimental subjects studied the materials in an individualized fashion wherein items missed were repeated and items mastered were skipped. Each yoked control got the identical materials his experimental partner used in the process of reaching a predetermined criterion of lesson mastery. There proved to be no significant differences between the subjects using the two formats in terms of either days to criterion, minutes to criterion, or errors to criterion. Further, when tested upon the items of the alternate format, neither group evinced any transfer of training. The yoked controls spent less time studying than their experimental partners, and the controls of the Confounded Format performed more poorly than their experimental partners on a retention test.

In the second experiment each of two matched groups of ninth-graders read both lesson formats, 30 students getting the two formats in the order Incisive-Confounded, and 28 in the order Confounded-Incisive. The Confounded-Incisive group required fewer days of instruction, required

fewer exposures to the self-test items, and committed fewer errors than the Incisive-Confounded group in reaching the same criterion of lesson mastery. Also, transfer of training was evinced between the two formats in the form of a reduction in both items and errors to criterion as the subjects shifted from the first to the second format. These reductions in items encountered and errors committed were accompanied by an increase in study time which appeared to reflect the students' effort to apply information already acquired as opposed to passively guessing.

The results were interpreted as in keeping with the premise that individualized instruction is particularly effective only in the latter stages of learning where ignorance becomes correspondingly individualized. The Incisive Format was particularly effective only when the subjects had already studied the Confounded Format. However, since Incisive and Confounded Formats appear to teach complementary aspects of a lesson, (i.e., transfer of training between the two is slight), any program of individualized instruction should properly incorporate both types of items. This being the case, it follows from the present results that the confounded items should precede the incisive ones during the student's course of study.

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APPENDIX A

Basic text of the lesson:

"Some Functional Anatomy of Human Vision"

NAME: ______________________________

Please read this lesson rapidly, going through it just once. Write here the time you begin reading: Time started__________

Some Functional Anatomy of Human Vision

The sense of sight is a complex function of an involved psychophysiological system incorporating many neural, muscular, and optical components. However, viewed simply, vision may be thought of as a function, principally, of three components, or types of components: (a) the eyes, (b) the occipital lobes or visual centers of the brain, and (c) the nerve cells or neurons which connect the eyes with the occipital lobes. These components are drawn in Figures 1 and 2 and are described in detail below. Be sure to look at the figures as well as to read this text.

The eye is a hollow ball of tough white tissue called the sclerotic coat. The eyeball contains a transparent semifluid called humor, and is so constructed as to be able to perform the functions of a camera. The inner surface of the eyeball is lined with several layers of nerve cells comprising what is called the retina including the specialized light sensitive cells which correspond to the film of a camera. Protecting the retina from stray light is an opaque (light proof) coat of pigmented (darkly colored) tissue called the choroid. The choroid lies between the retina and the inner surface of the sclerotic coat, surrounding the eye except in front. In front, the transparent cornea admits light which, on its course to the retina, must pass, as must the light entering a camera, through a small aperture, the pupil, surrounded by a disk of pigmented muscle tissue called the iris. Next, this light passes through a lens, which by means of its curved surfaces so bends light that it is brought to a focus on the photosensitive retina. Both the size of the pupil and the shape of the lens are adjustable, insuring a clear retinal image of the observed or fixated object under various conditions of illumination and at various distances of regard.

Light entering the eye from an object in the visual field is focused upon the center of the retina at a point called the fovea. Or, stated differently, the section of the retinal image focused upon the fovea or center of the retina represents that point on a distant object which the eye is fixating, or looking at. Because of the optical characteristics of the lens, the retinal image is inverted both horizontally (that is left becomes right and right becomes left) as well as vertically (that is upside down). Hence, objects or parts of objects in the right half of the visual field (to the right of the fixation point) are projected onto the left half of each retina, whereas objects, or parts of objects in the left half of the visual field are "seen" by the right half of each retina. See Figure 2.

The retina incorporates three main groups of neurons (nerve cells) arranged in three layers: the photoreceptors, the bipolar neurons, and the ganglion neurons. The outermost layer next to the pigmented choroid coat is composed of the highly specialized neurons called rods and cones which contain the chemical materials responsive to light. The rods are more sensitive than the cones and are responsible for vision in dim light, so-called "night vision." Rods are color-blind, seeing only degrees of brightness; they are located in the periphery (outer boundary) of the retina. The cones, located primarily in and near the fovea, see color and are responsible for daylight vision. People without cones are completely color blind, see best in dim light and see only out of the "corner" of their eyes, i.e., their foveas are blind. People with defective rods on the other hand experience what is called "night blindness": they cannot see in dim light. These photosensitive cells, rods and cones alike, generate electrochemical signals, called neural impulses, to be transmitted to other parts of the visual system. Making synape (or electrochemical connection) with these primary receptive neurons are the bipolar neurons of the second layer which transmit impulses or neural signals to the third group, the ganglion cells. The axons, or wirelike extensions of the ganglion cells run over the inner surface of the retina, converging at the optic disk or blind spot, somewhat medial[1] to the center of the retina where they exit the eyeball in a bundle to form the optic nerve. The optic disk is "blind" because it contains no rods or cones, only ganglion-cell axons.

Directed backward and medially, the optic nerves of the two eyes come together at a point near the base of the brain. Here at the optic chiasma, each nerve divides into two branches so that one branch contains fibers projecting from the lateral (toward the temple) half of the retina while the other branch contains fibers projecting from the medial (toward the nose) half of the retina. In turn, the medial branch of each optic nerve crosses over to join the lateral branch of the other optic nerve to form, thereby, the right and left optic tracts. From the optic chiasma the two optic tracts project through subcortical centers to the cerebrum, the major division of the human brain.

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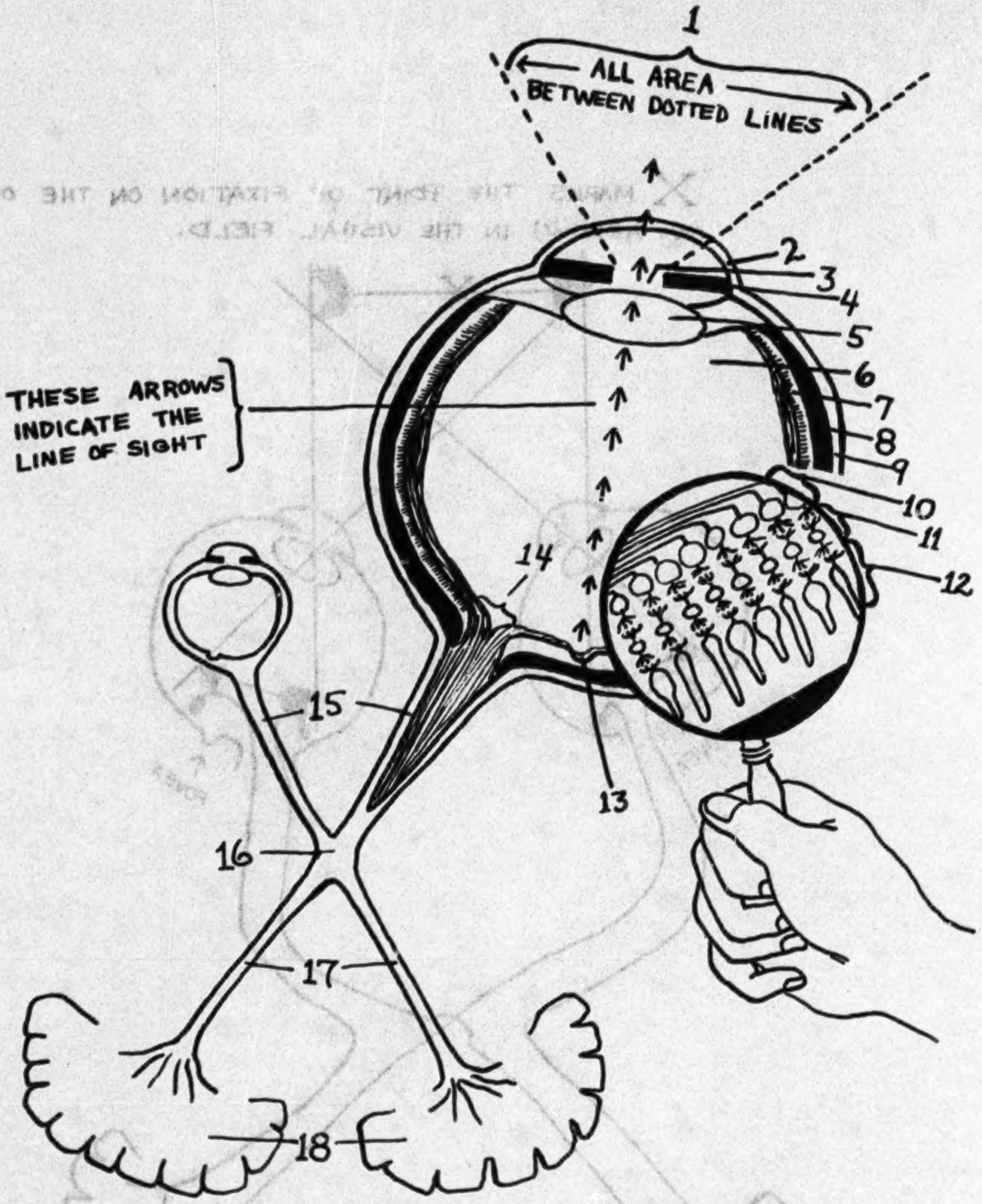
[1] Medial means "toward the midline or center of the head and body;" lateral, the opposite, means "toward the side(s) of the head and body." For example, the eyes are medial to the ears but lateral to the nose.

The cerebrum or cerebral cortex (meaning "rind" or "covering") is so large that it virtually lines the inner surface of the skull, enveloping the other divisions of the brain beneath it. The surface of the cerebrum is highly convoluted (creased and folded) and is divided into two symmetrical halves or hemispheres by a deep longitudinal fissure or crease that runs along the midline. Located in the dorsal (back of the head) portion of each of these hemispheres is a visual center known as the occipital lobe. The fibers of the right optic tract project to the right occipital lobe, and the fibers of the left optic tract project to the left occipital lobe. Hence, the neural impulses generated in the rods and cones of the right half of each retina are transmitted to the right occipital lobe while impulses from the left half of each retina are transmitted to the left occipital lobe.

And so it is that information received optically by the eye, and transmitted neurally via the retina, optic nerves, and optic tracts to the occipital lobes of the brain comes finally to be perceived, to form the images which constitute the furniture of sight.

When you have finished reading, please note the time here and raise your hand.

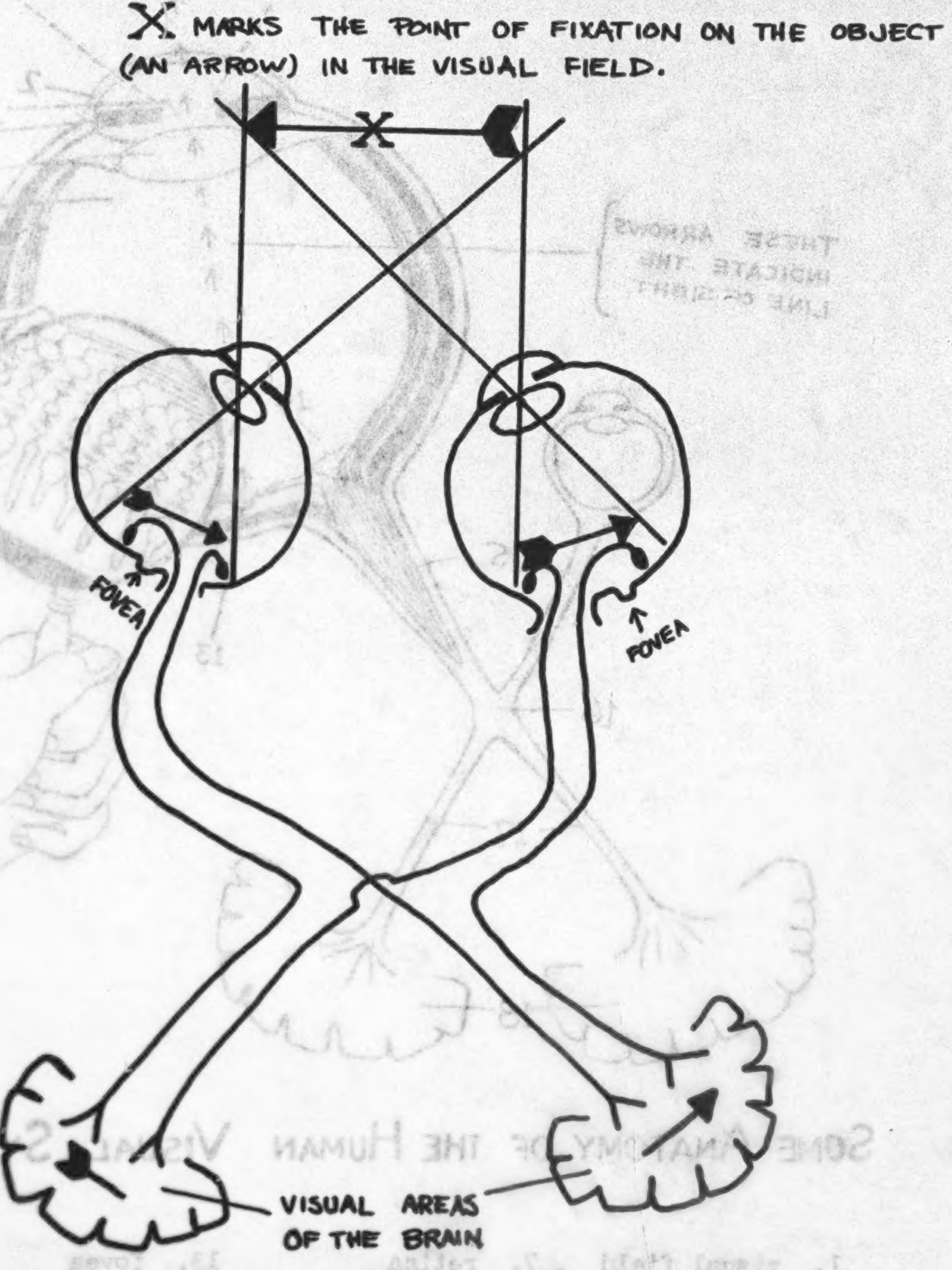
Time finished reading: ____________________


1
ALL AREA BETWEEN DOTTED LINES
THESE ARROWS INDICATE THE LINE OF SIGHT
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18

SOME ANATOMY OF THE HUMAN VISUAL SYSTEM

1. visual field
2. cornea
3. pupil
4. iris
5. lens
6. humor
7. retina
8. pigmented choroid coat
9. sclerotic coat
10. ganglion cells
11. bipolar cells
12. rods and cones
13. fovea
14. optic disk
15. optic nerves
16. optic chiasma
17. optic tracts
18. occipital lobes of the cerebrum or cerebral cortex

Figure I


X MARKS THE POINT OF FIXATION ON THE OBJECT (AN ARROW) IN THE VISUAL FIELD.
X
FOVEA
FOVEA
VISUAL AREAS OF THE BRAIN

SOME FUNCTIONAL ANATOMY OF HUMAN VISION

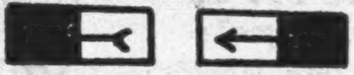
Figure II

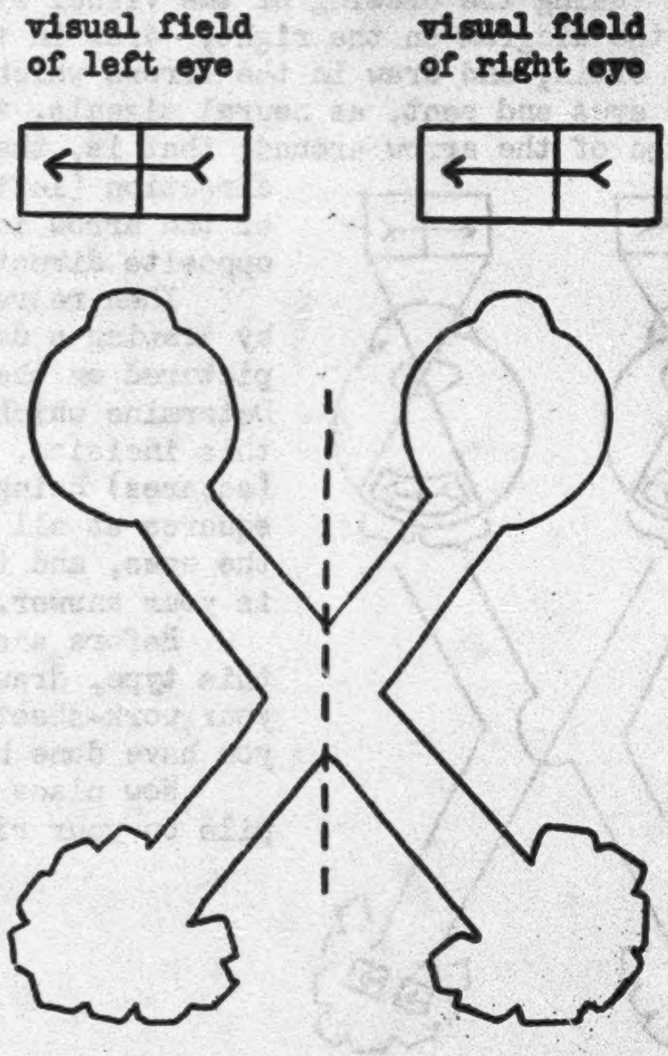
APPENDIX B

The 27 self-test items comprising the Incisive Format

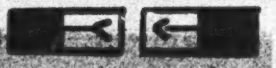
[redacted]

If the drawing on the right represents the visual system and the dotted line represents an incision (cut) what amount of blindness would result from that incision? Block out that part of the visual field of each eye which the victim cannot see.

For example,  **means the victim cannot see things in the left half of the visual field with his left eye (can't see arrowhead), nor things in the right half of the visual field with his right eye (can't see arrow feathers).**



(1011) q

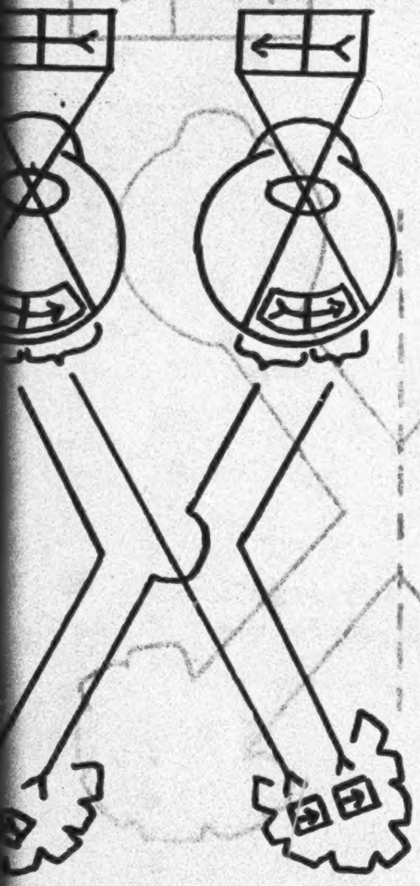
Answer:  If you were correct, go to the next tablet; if wrong, read below:

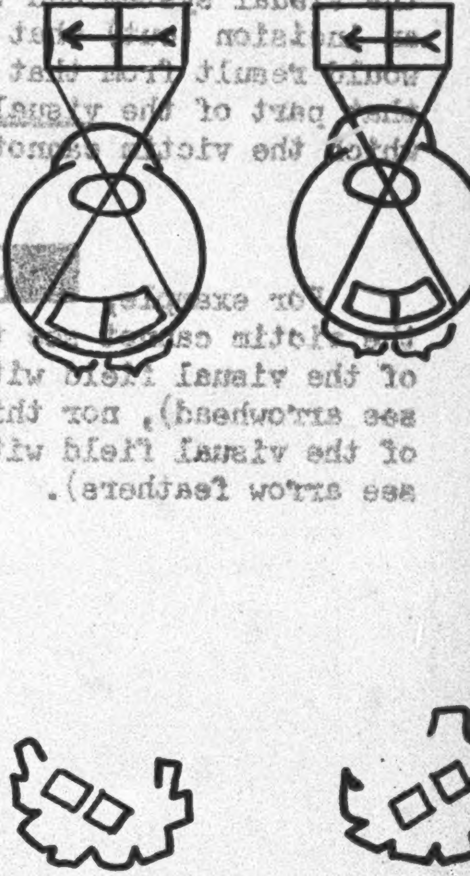
Using the drawing of the visual system on the left as a model, fill in the missing parts in the diagram on the right; draw in the four types of neural fibers going from the eyes to the brain, and draw in the arrows which represent the images (or pictures) being picked up by the eyes and sent, as neural signals, to the brain. Note that the lens of each eye turns the image of the arrow around; that is, the arrow being viewed in the visual field points one direction (left) while the image (or picture) of the arrow in the eyeball points the opposite direction (to the right).

Then represent the incision in question by drawing a dotted line like the one pictured on the reverse side of this page. Determine which neural fibers are cut by this incision, and block out the signals (squares) being blocked. Block out the squares at all three levels: the brain, the eyes, and the visual field. The last is your answer.

Before answering the next question of this type, draw yourself such a diagram on your work-sheet and solve the problem as you have done here.

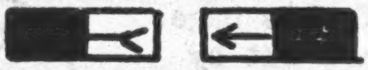
Now place this tablet on the correct pile on your right.

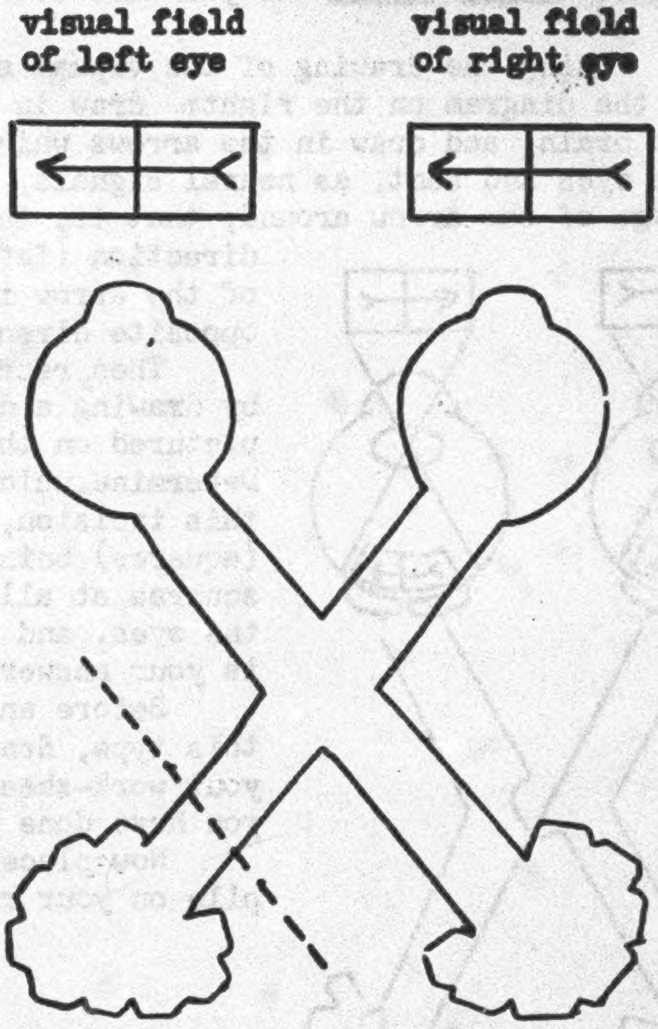




[redacted]

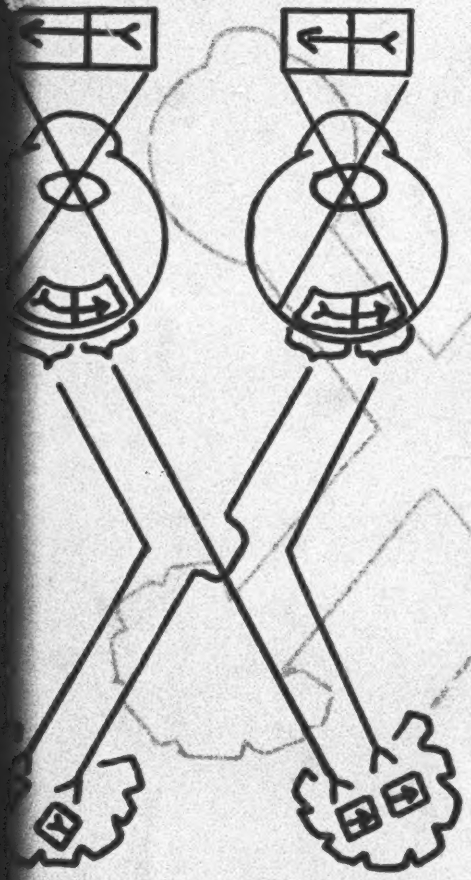
If the drawing on the right represents the visual system and the dotted line represents an incision (cut) what amount of blindness would result from that incision? Block out that part of the *visual field* of each eye which the victim cannot see.

For example,  **means the victim cannot see things in the left half of the visual field with his left eye (can't see arrowhead), nor things in the right half of the visual field with his right eye (can't see arrow feathers).**



Answer: ← ← If you were correct, go to the next tablet; if wrong, read below:

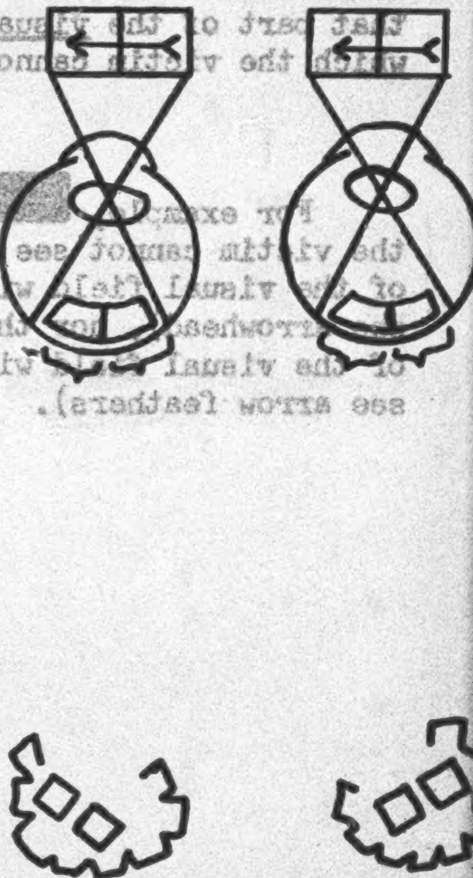
Using the drawing of the visual system on the left as a model, fill in the missing parts in the diagram on the right: draw in the four types of neural fibers going from the eyes to the brain, and draw in the arrows which represent the images (or pictures) being picked up by the eyes and sent, as neural signals, to the brain. Note that the lens of each eye turns the image of the arrow around; that is, the arrow being viewed in the visual field points one direction (left) while the image (or picture) of the arrow in the eyeball points the opposite direction (to the right).



Then, represent the incision in question by drawing a dotted line like the one pictured on the reverse side of this page. Determine which neural fibers are cut by this incision, and block out the signals (squares) being blocked. Block out the squares at all three levels: the brain, the eyes, and the visual field. The last is your answer.

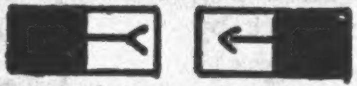
Before answering the next question of this type, draw yourself such a diagram on your work-sheet and solve the problem as you have done here.

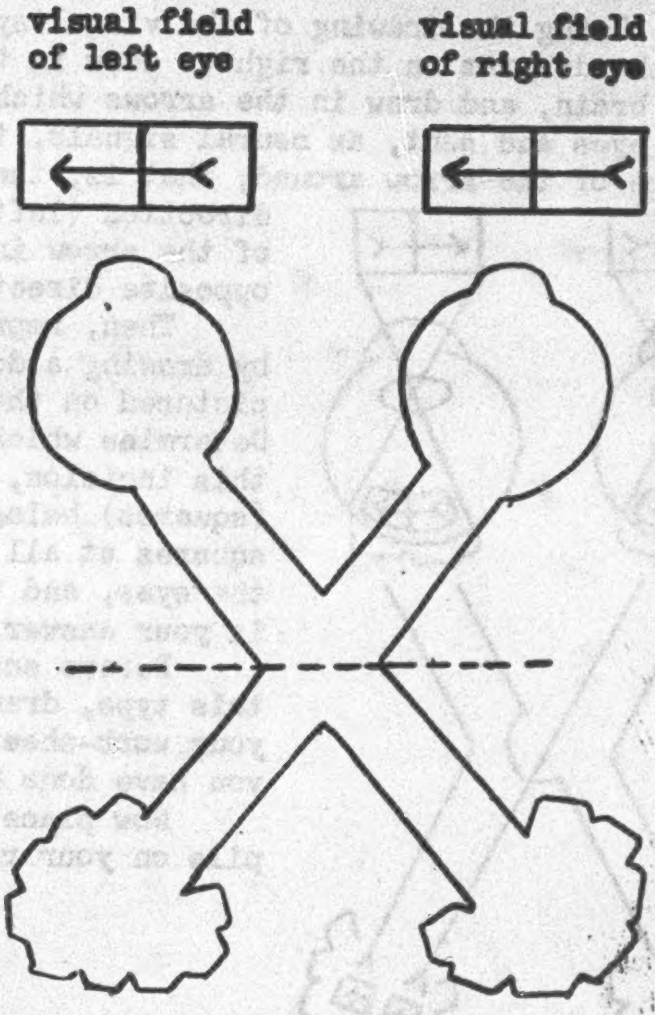
Now place this tablet on the correct pile on your right.



[redacted]

If the drawing on the right represents the visual system and the dotted line represents an incision (cut) what amount of blindness would result from that incision? Block out that part of the visual field of each eye which the victim cannot see.

For example,  **means the victim cannot see things in the left half of the visual field with his left eye (can't see arrowhead), nor things in the right half of the visual field with his right eye (can't see arrow feathers).**



(1031) q

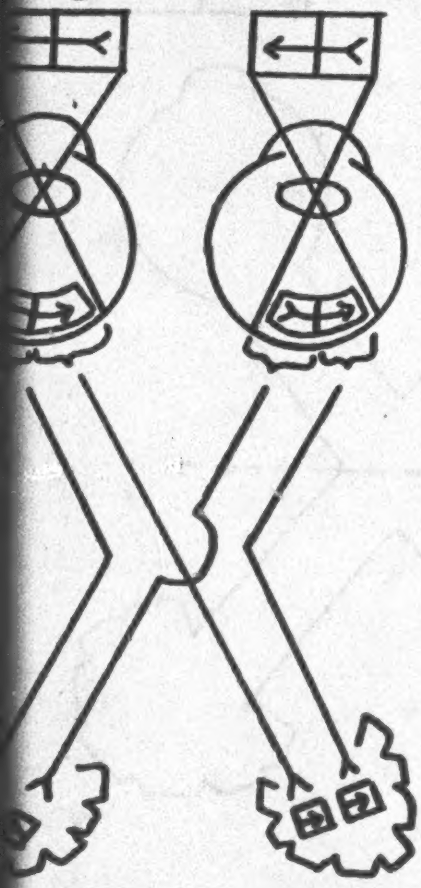
Answer: [redacted] [redacted] If you were correct, go to the next tablet; if wrong, read below:

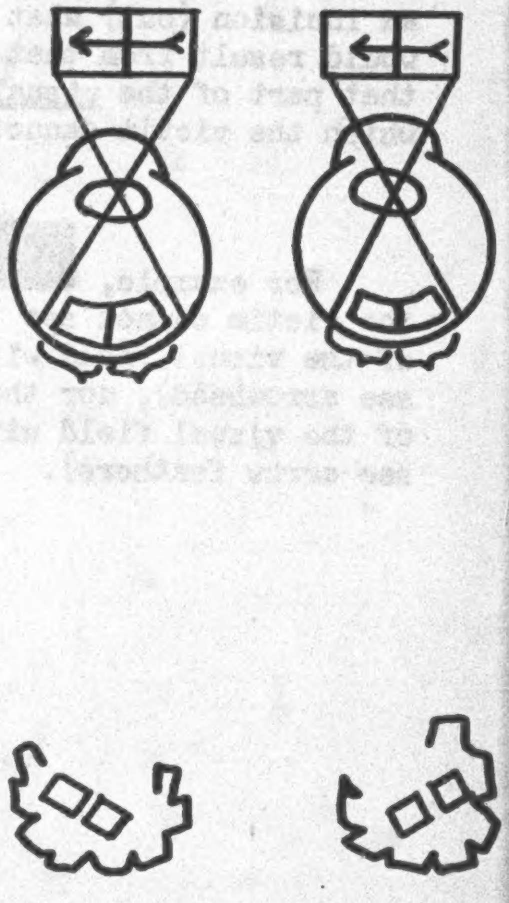
Using the drawing of the visual system on the left as a model, fill in the missing parts in the diagram on the right: draw in the four types of neural fibers going from the eyes to the brain, and draw in the arrows which represent the images (or pictures) being picked up by the eyes and sent, as neural signals, to the brain. Note that the lens of each eye turns the image of the arrow around; that is, the arrow being viewed in the visual field points one direction (left) while the image (or picture) of the arrow in the eyeball points the opposite direction (to the right).

Then, represent the incision in question by drawing a dotted line like the one pictured on the reverse side of this page. Determine which neural fibers are cut by this incision, and block out the signals (squares) being blocked. Block out the squares at all three levels: the brain, the eyes, and the visual field. The last is your answer.

Before answering the next question of this type, draw yourself such a diagram on your work-sheet and solve the problem as you have done here.

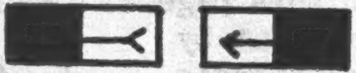
Now place this tablet on the correct pile on your right.

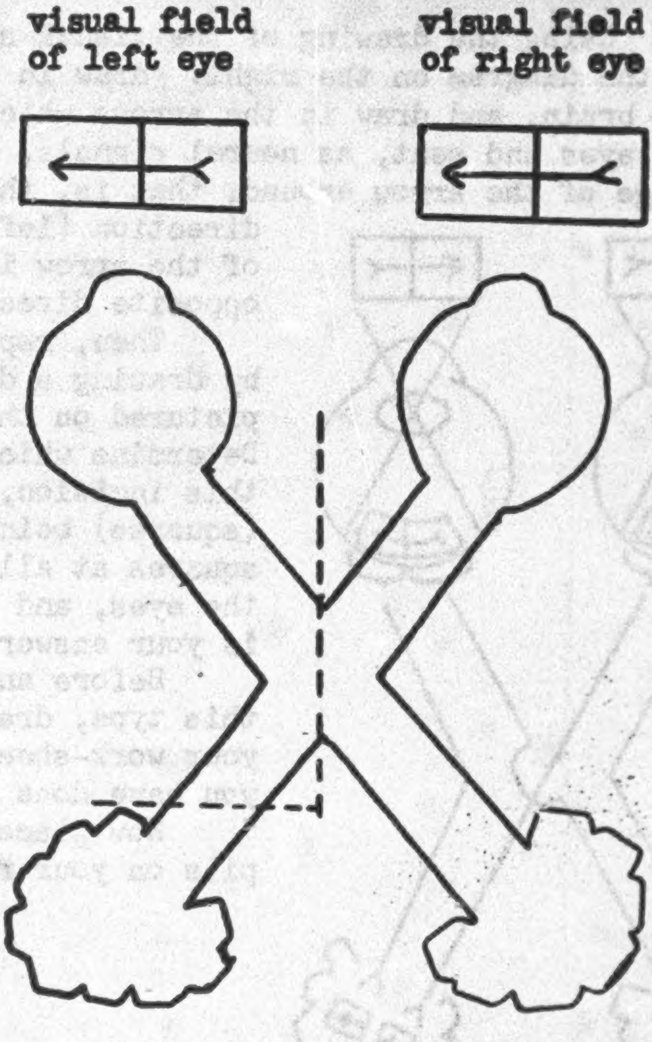




[redacted]

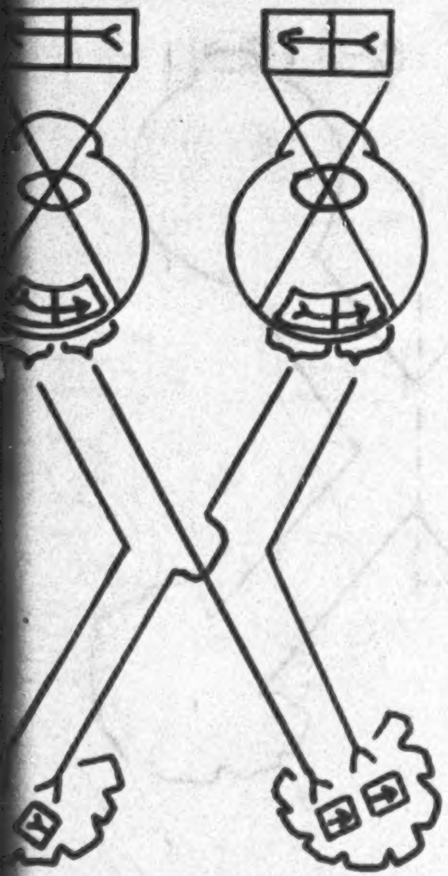
If the drawing on the right represents the visual system and the dotted line represents an incision (cut) what amount of blindness would result from that incision? Block out that part of the visual field of each eye which the victim cannot see.

For example,  means the victim cannot see things in the left half of the visual field with his left eye (can't see arrowhead), nor things in the right half of the visual field with his right eye (can't see arrow feathers).



Answer: ■ [←] If you were correct, go to the next tablet; if wrong, read below:

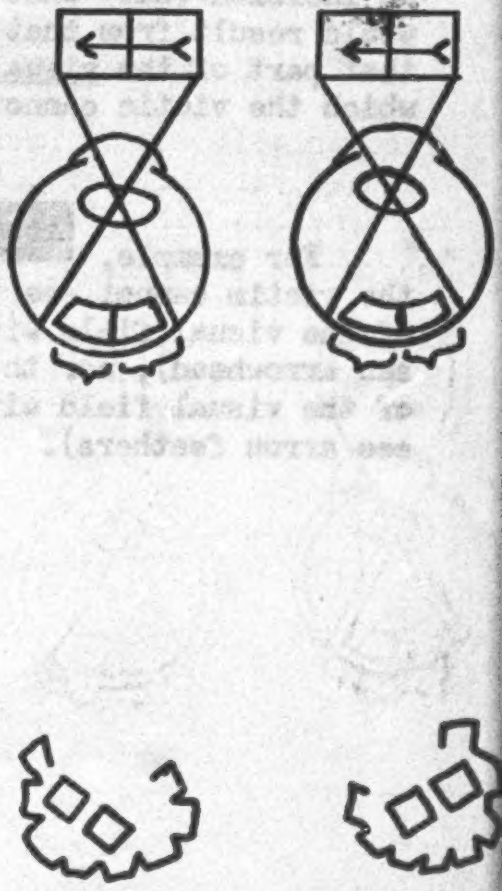
Using the drawing of the visual system on the left as a model, fill in the missing parts in the diagram on the right: draw in the four types of neural fibers going from the eyes to the brain, and draw in the arrows which represent the images (or pictures) being picked up by the eyes and sent, as neural signals, to the brain. Note that the lens of each eye turns the image of the arrow around; that is, the arrow being viewed in the visual field points one direction (left) while the image (or picture) of the arrow in the eyeball points the opposite direction (to the right).



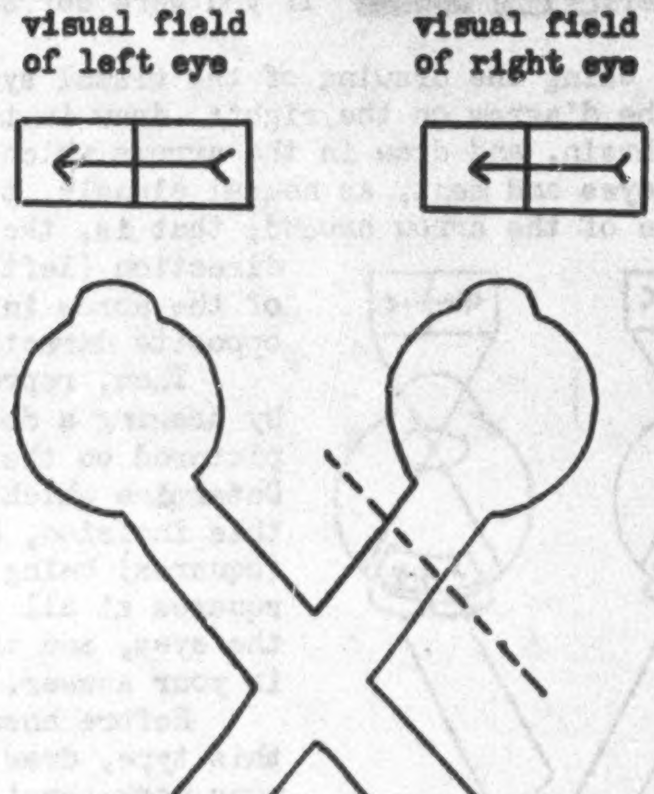
Then, represent the incision in question by drawing a dotted line like the one pictured on the reverse side of this page. Determine which neural fibers are cut by this incision, and block out the signals (squares) being blocked. Block out the squares at all three levels: the brain, the eyes, and the visual field. The last is your answer.

Before answering the next question of this type, draw yourself such a diagram on your work-sheet and solve the problem as you have done here.

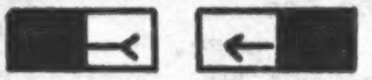
Now place this tablet on the correct pile on your right.



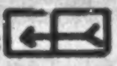
[redacted]



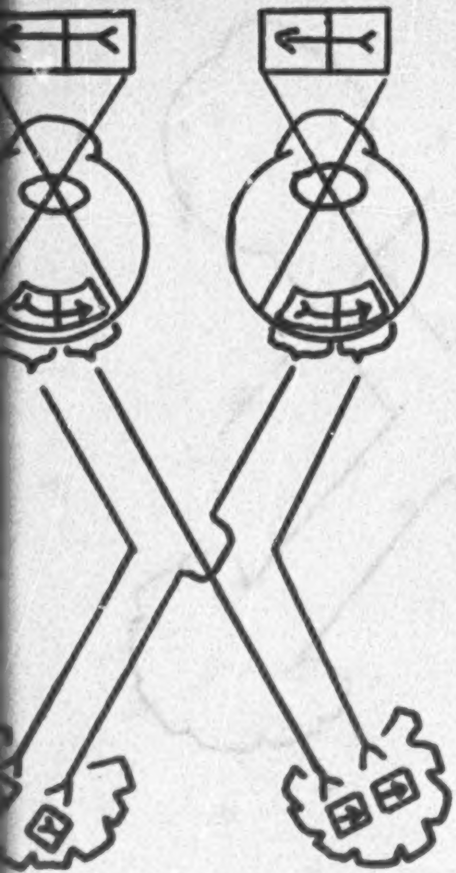
If the drawing on the right represents the visual system and the dotted line represents an incision (cut) what amount of blindness would result from that incision? Block out that part of the visual field of each eye which the victim cannot see.

For example,  means the victim cannot see things in the left half of the visual field with his left eye (can't see arrowhead), nor things in the right half of the visual field with his right eye (can't see arrow feathers).

(1051) q

Answer:  [redacted] If you were correct, go to the next tablet; if wrong, read below:

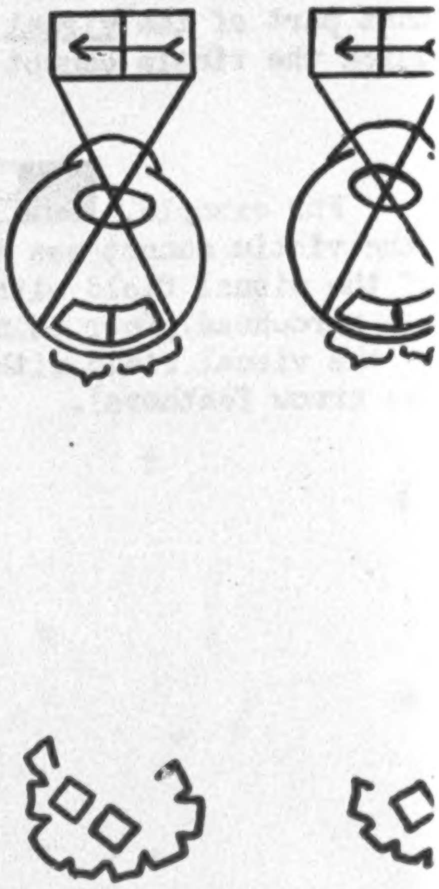
Using the drawing of the visual system on the left as a model, fill in the missing parts in the diagram on the right: draw in the four types of neural fibers going from the eyes to the brain, and draw in the arrows which represent the images (or pictures) being picked up by the eyes and sent, as neural signals, to the brain. Note that the lens of each eye turns the image of the arrow around; that is, the arrow being viewed in the visual field points one direction (left) while the image (or picture) of the arrow in the eyeball points the opposite direction (to the right).



Then, represent the incision in question by drawing a dotted line like the one pictured on the reverse side of this page. Determine which neural fibers are cut by this incision, and block out the signals (squares) being blocked. Block out the squares at all three levels: the brain, the eyes, and the visual field. The last is your answer.

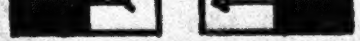
Before answering the next question of this type, draw yourself such a diagram on your work-sheet and solve the problem as you have done here.

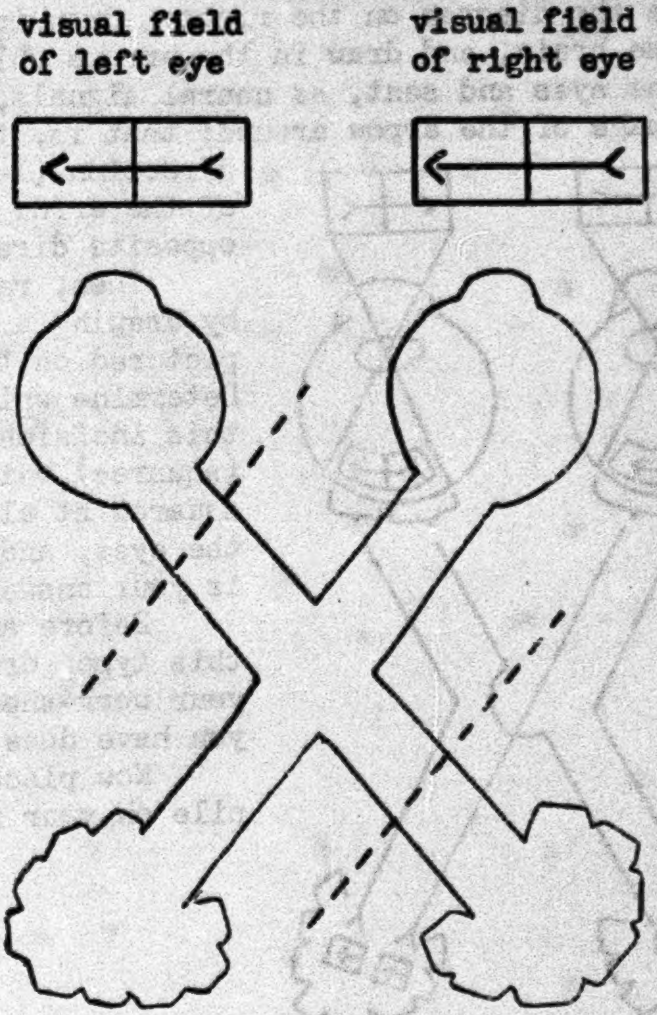
Now place this tablet on the correct pile on your right.

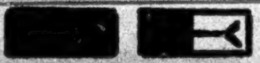


[redacted]

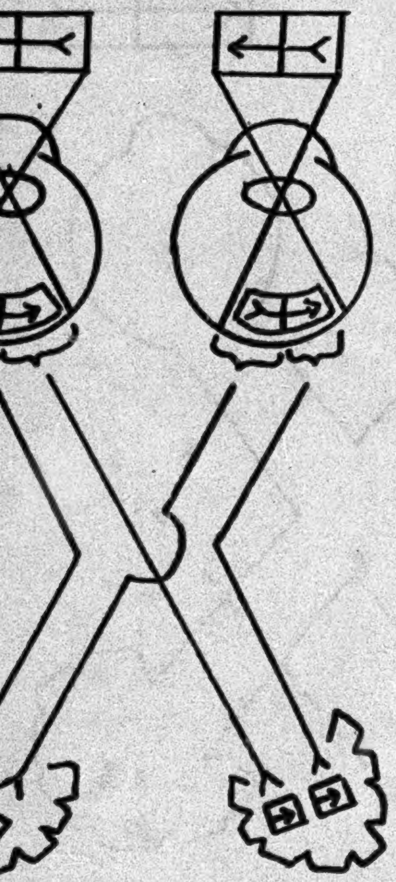
If the drawing on the right represents he visual system and the dotted line represents n incision (cut) what amount of blindness ould result from that incision? Block out hat part of the visual field of each eye hich the victim cannot see.

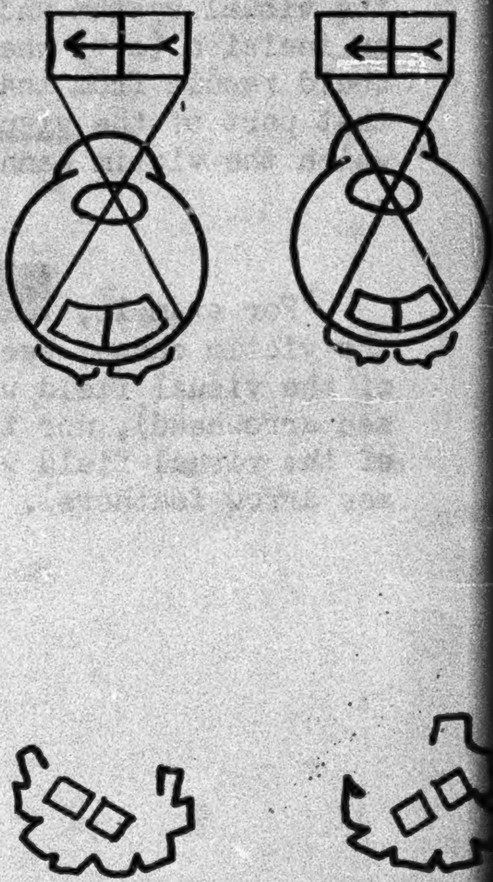
For example,  means he victim cannot see things in the left half f the visual field with his left eye (can't ee arrowhead), nor things in the right half f the visual field with his right eye (can't ee arrow feathers).



nswer:  If you were correct, go to the next tablet; if wrong, read below:

Using the drawing of the visual system on the left as a model, fill in the missing parts n the diagram on the right: draw in the four types of neural fibers going from the eyes to he brain, and draw in the arrows which represent the images (or pictures) being picked up by he eyes and sent, as neural signals, to the brain. Note that the lens of each eye turns the mage of the arrow around; that is, the arrow being viewed in the visual field points one direction (left) while the image (or picture) of the arrow in the eyeball points the opposite direction (to the right).





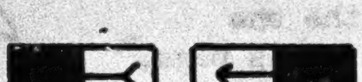
Then, represent the incision in question by drawing a dotted line like the one pictured on the reverse side of this page. Determine which neural fibers are cut by this incision, and block out the signals (squares) being blocked. Block out the squares at all three levels: the brain, the eyes, and the visual field. The last is your answer.

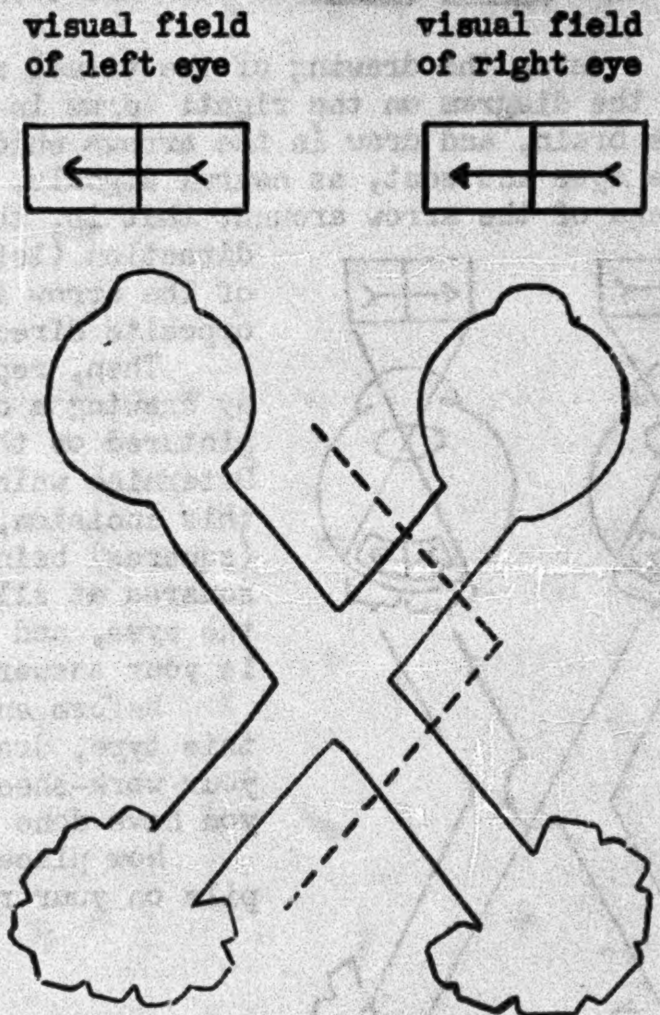
Before answering the next question of this type, draw yourself such a diagram on your work-sheet and solve the problem as you have done here.

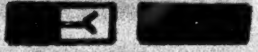
Now place this tablet on the correct pile on your right.

[redacted]

If the drawing on the right represents he visual system and the dotted line represents n incision (cut) what amount of blindness ould result from that incision? Block out hat part of the **visual field** of each eye hich the victim cannot see.

For example,  means he victim cannot see things in the left half f the visual field with his left eye (can't ee arrowhead), nor things in the right half f the visual field with his right eye (can't ee arrow feathers).



nswer:  If you were correct, go to the next tablet; if wrong, read below:

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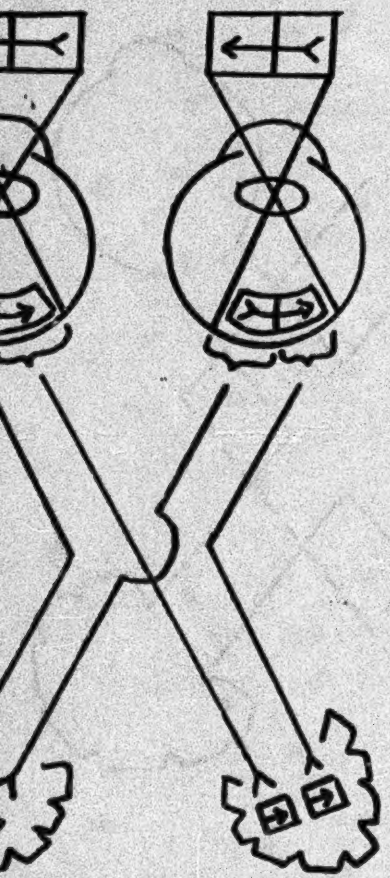

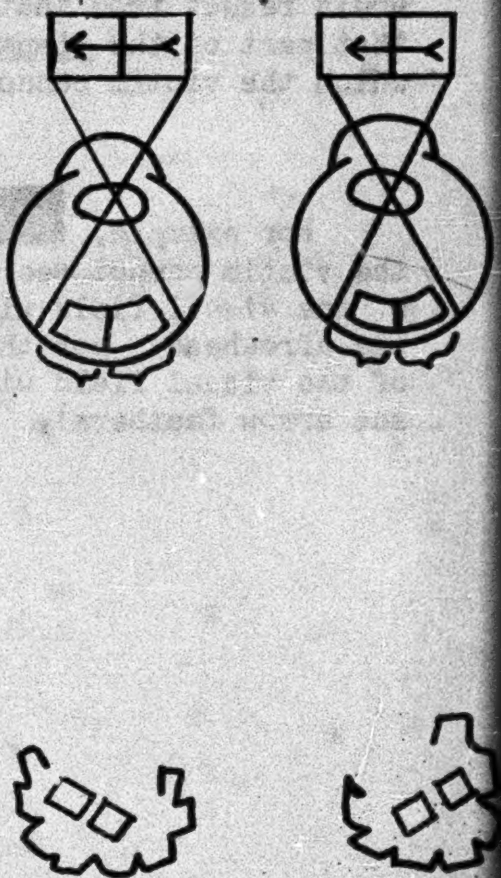

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Before answering the next question of this type, draw yourself such a diagram on your work-sheet and solve the problem as you have done here.

Now place this tablet on the correct pile on your right.

The eye is a hollow ball of tough white tissue called the ____________ coat.

(Item 9 in Figure 3)

(108i)q

Light is focused upon the rear, inner surface of the eyeball by means of a curved ________________.

(Item 5 in Figure 3)

(109i)q

Sclerotic

If you spelled your answer wrong, write the correct spelling here and place the tablet on the correct pile to your right:

____

(108i) a

Lens

If you spellec your answer wrong, write the correct spelling here and place the tablet on the correct pile to your right:

____

(109i) a

That part of the environment visible to the eye is called the _________ _________.

(Item 1 in Figure 3)

(110i)q

Between the photoreceptors and the cells whose axons (wire-like fibers) leave the eye are a layer of neurons called _______________neurons.

(Item 11 in Figure 3)

(111i)q

Visual field

If you spelled your answer wrong, write the correct spelling here and place the tablet on the correct pile to your right:

____________ ____________

(110i) a

Bipolar

If you spelled your answer wrong, write the correct spelling here and place the tablet on the correct pile to your right:

____

(111i) a

Light entering the eyeball passes through a hole in the center of a disk of pigmented (eye-colored) tissue; the hole is called the ________________.

(Item 3 in Figure 3)

(112i) q

The neurons whose axone (wire-like fibers) traverse the innermost surface of the eyeball and extend from the eye are called ___________ cells.

(Item 10 in Figure 3)

(113i) q

Pupil

If you spelled your answer wrong, write the correct spelling here and place the tablet on the correct pile to your right:

____

(112i) a

Ganglion

If you spelled your answer wrong, write the correct spelling here and place the tablet on the correct pile to your right:

____

(113i) a

The pnotoreceptors responsible for
daylight, color vision are called __________.

(Part of item 12 in Figure 3)

(114i) q

Light entering the eyeball passes
through a hole in th center of a disk of
pigmented (eye-colored) muscle tissue; the
muscle is called the _______________.

(Item 4 in Figure 3)

(115i)q

Cones

If you spelled your answer wrong, write the correct spelling here and place the tablet on the correct pile to your right:

____

(114i) a

Iris

If you spelled your answer wrong, write the correct spelling here and place the tablet on the correct pile to your right:

____

(115i) a

The eyeball contains a transparent semifluid called ________________.

(Item 6 in Figure 3)

(116i) q ________

A bundle of axons exit the eye at the blind spot called the ________ ____________.

(Item 14 in Figure 3)

(117i) q

________ ________

Humor

If you spelled your answer wrong, write the correct spelling here and place the tablet on the correct pile to your right:

____

(116i) a

Optic Disk

If you spelled your answer wrong, write the correct spelling here and place the tablet on the correct pile to your right:

__________ ____________

(117i) a

Rods

If you spelled your answer wrong, write the correct spelling here and place the tablet on the correct pile to your right:

____

(118i) a

Cornea

If you spelled your answer wrong, write the correct spelling here and place the tablet on the correct pile to your right:

____

(119i) a

The photoreceptors responsible for night vision are called ____________

(Part of item 12 in Figure 3)

(118i) q

The bulging, transparent window at the front of the eye is called the

__________________________.

(Item 2 in Figure 3)

(119i)q

Choroid

If you spelled your answer wrong, write the correct spelling here and place the tablet on the correct pile to your right:

____________ ________________

(120i) a

Fovea

If you spelled your answer wrong, write the correct spelling here and place the tablet on the correct pile to your right:

____

(121i) a

Lying between the outermost and innermost surfaces of the eyeball is an opaque (light proof) coat of pigmented (colored) tissue called the ______________________.

(Item 8 in Figure 3)

(120i) q

The retinal image of an object being fixated is projected onto the center of the retina in a region called the ____________.

(Item 13 in Figure 3)

(121i) q

Located in the dorsal (back of the head) portion of each hemisphere of the brain is a visual center known as the ___________ ___________.

(Item 18 in Figure 3)

(122i) q

On their way to the brain, the bundles of axons from the two eyes intersect. On the eye side of this intersection the bundles are called the ________________ ______________.

(Item 15 in Figure 3)

(123i) q

Occipital lobe

If you spelled your answer wrong, write the correct spelling here and place the tablet on the correct pile to your right:

_____________ _____________

(122i) a

Optic Nerves

If you spellec your answer wrong, write the correct spelling here and place the tablet on the correct pile to your right:

_________ ___________

(123i) a

The innermost surface of the eyeball is lined with three layers of nerve cells comprising what is called the ______________.

(Item 7 in Figure 3)

(124i) q

The bundles of axons coming from the two eyes intersect at the ___________ ___________.

(Item 16 in Figure 3)

(125i) q

Retina

If you spelled your answer wrong, write the correct spelling here and place the tablet on the correct pile to your right:

____

(124i) a

Optic Chiasma

If you spelled your answer wrong, write the correct spelling here and place the tablet on the correct pile to your right:

__________ ____________

(125i) a

Optic Tracts

If you spelled your answer wrong, write the correct spelling here and place the tablet on the correct pile to your right:

____________ ________________

(126i) a

Cerebrum

Cerebral cortex

If you spelled your answers wrong, write the correct spelling here and place the tablet on the correct pile to your right:

____________ **or** ____________ ________________

(127i) a

On their way to the brain, the bundles of axons from the two eyes intersect. On the brain side of this intersection the bundles are called the __________ __________

(Item 17 in Figure 3)

(126i) q

The major division of the homan brain is called the ____________, or the ______________ ______________.

(Item 18 in Figure is a part Of this major division)

(127i) q

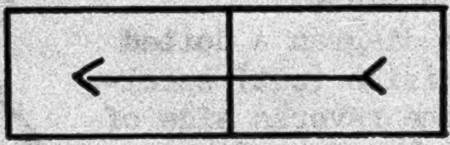
APPENDIX C

The 27 self-test items comprising the Confounded Format

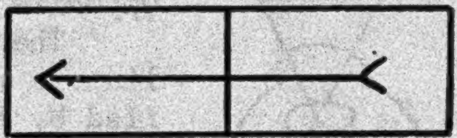
[redacted]

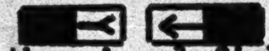
If one cut the optic chiasma down the middle, separating right side from left side, what would be the extent of the blindness?

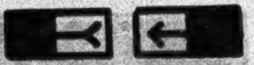
Visual field of left eye



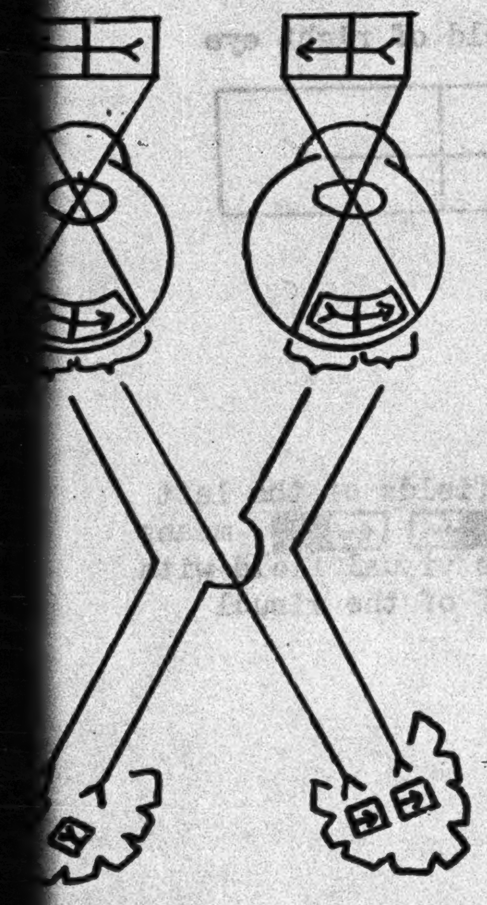
Visual field of right eye



Using pen or pencil, black out that portion of the visual fields of the left and right eyes no longer visible to the victim. For example,  means that the victim can no longer see things in the left half of the visual field with his left eye (can't see arrowhead), nor things in the right half of the visual field with his right eye (can't see arrow feathers).

Answer:  If you were correct, go to next tablet; if wrong, read below:

Using the drawing of the visual system on the left as a model, fill in the missing parts in the diagram on the right: draw in the four types of neural fibers going from the eyes to the brain, and draw in the arrows which represent the images (or pictures) being picked up by the eyes and sent, as neural signals, to the brain. Note that the lens of each eye turns the image of the arrow around; that is, the arrow being viewed in the visual field points one direction (left) while the image (or picture) of the arrow in the eyeball points the opposite direction (to the right).

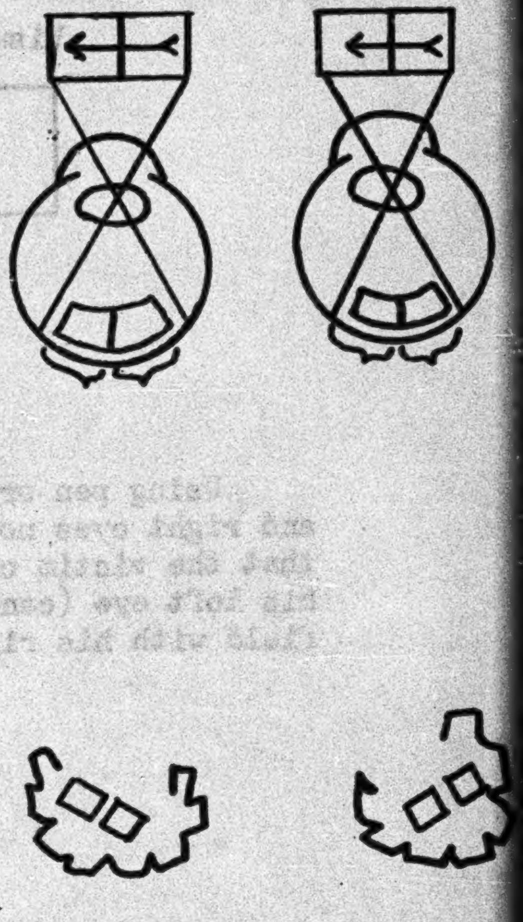


Then, draw into your diagram a dotted line representing the incision (cut) specified by the question on the reverse side of this page. Determine which neural fibers are cut by this incision and block out the signals (squares) being blocked. Block out the squares at all three levels: the brain, the eye, and the visual field. The last is your answer.

Before answering the next question of this type, draw yourself such a diagram on your work-sheet and solve the problem just as you have done here.

The optic chiasma is item 16 in Figure 3.

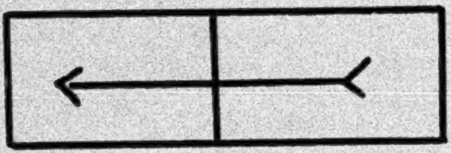
Now place this tablet on the correct pile on your right.



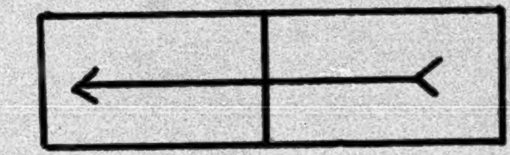
[redacted]

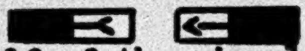
If one cut completely through the left optic tract, what would be the extent of the blindness?

Visual field of left eye



Visual field of right eye

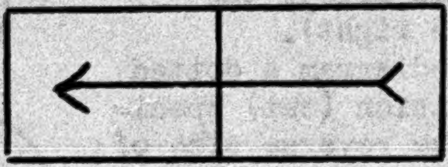


Using pen or pencil, black out that portion of the visual fields of the left and right eyes no longer visible to the victim. For example,  means that the victim can no longer see things in the left half of the visual field with his left eye (can't see arrowhead), nor things in the right half of the visual field with his right eye (can't see arrow feathers).

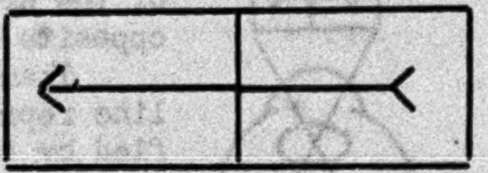
[redacted]

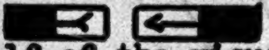
If one cut completely through the optic chiasma separating front half from back half, what would be the extent of the blindness?

Visual field of left eye



Visual field of right eye



Using pen or pencil, black out that portion of the visual fields of the left and right eyes no longer visible to the victim. For example,  means that the victim can no longer see things in the left half of the visual field with his left eye (can't see arrowhead), nor things in the right half of the visual field with his right eye (can't see arrow feathers).

Answer: [redacted] [redacted] If you were correct, go to next tablet; if wrong, read below:

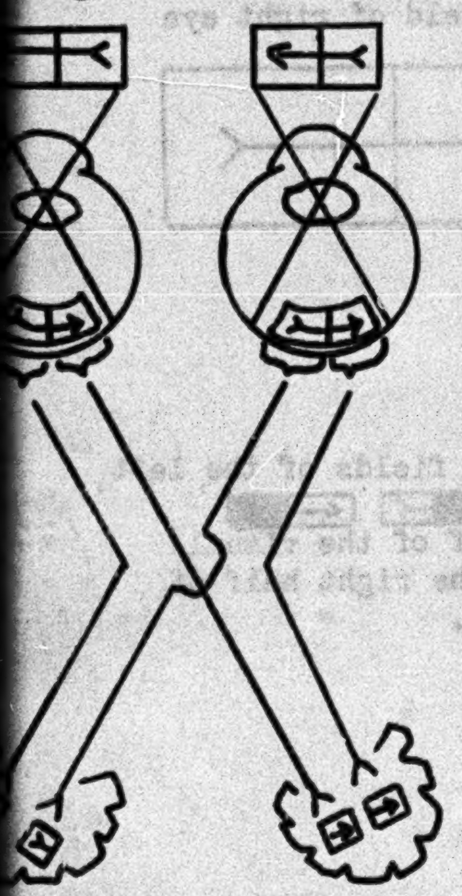
Using the drawing of the visual system on the left as a model, fill in the missing parts in the diagram on the right: draw in the four types of neural fibers going from the eyes to the brain, and draw in the arrows which represent the images (or pictures) being picked up by the eyes and sent, as neural signals, to the brain. Note that the lens of each eye turns the image of the arrow around; that is, the arrow being viewed in the visual field points one direction (left) while the image (or picture) of the arrow in the eyeball points the opposite direction (to the right).

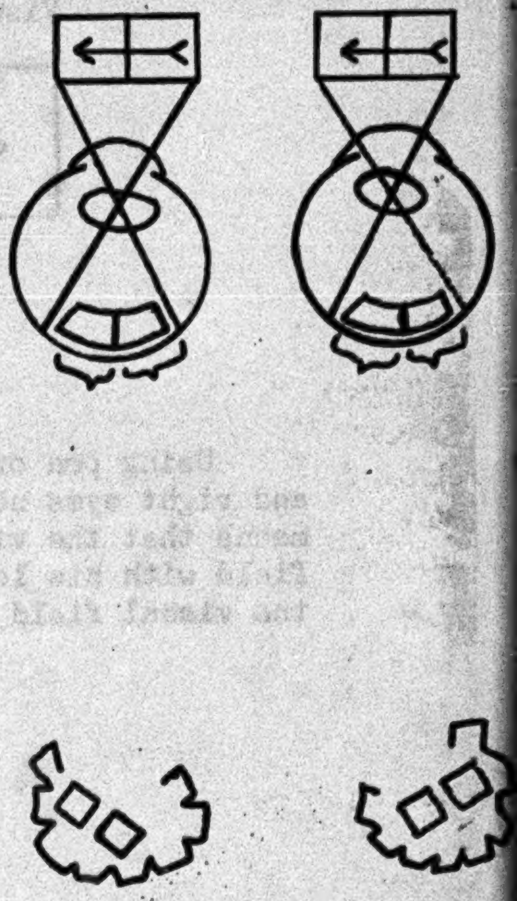
Then, draw into your diagram a dotted line representing the incision (cut) specified by the question on the reverse side of this page. Determine which neural fibers are cut by this incision and block out the signals (squares) being blocked. Block out the squares at all three levels: the brain, the eye, and the visual field. The last is your answer.

Before answering the next question of this type, draw yourself such a diagram on your work-sheet and solve the problem just as you have done here.

The optic chiasma is item 16 in Figure 3.

Now place this tablet on the correct pile on your right.

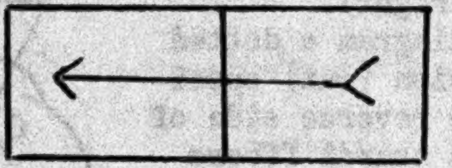




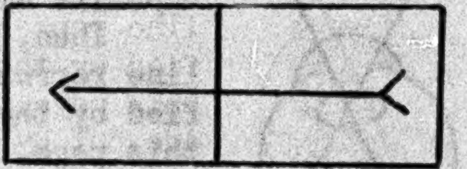
[redacted]

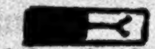
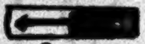
If one cut the optic chiasma down the middle separating right side from left side, and also cut completely through the left optic tract, what would be the extent of the blindness?

Visual field of left eye



Visual field of right eye



Using pen or pencil, black out that portion of the visual fields of the left and right eyes no longer visible to the victim. For example,   **means that the victim can no longer see things in the left half of the visual field with his left eye (can't see arrowhead), nor things in the right half of the visual field with his right eye (can't see arrow feathers).**

Answer: ■ ← If you were correct, go to next tablet; if wrong, read below:

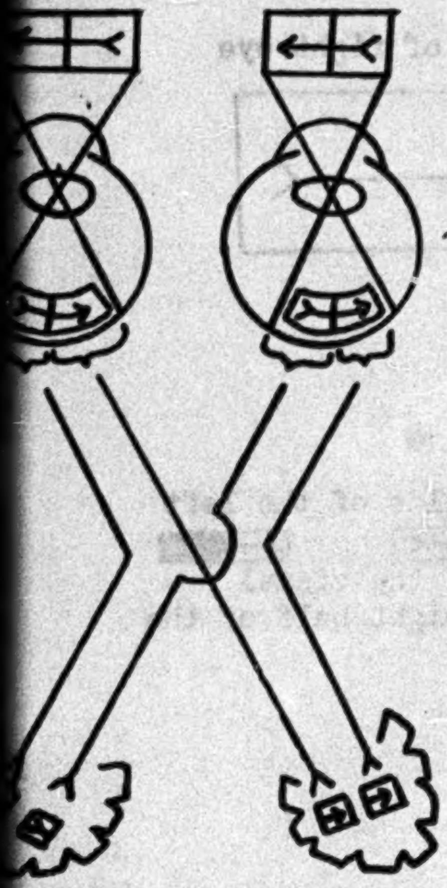
Using the drawing of the visual system on the left as a model, fill in the missing parts in the diagram on the right: draw in the four types of neural fibers going from the eyes to the brain, and draw in the arrows which represent the images (or pictures) being picked up by the eyes and sent, as neural signals, to the brain. Note that the lens of each eye turns the image of the arrow around; that is, the arrow being viewed in the visual field points one direction (left) while the image (or picture) of the arrow in the eyeball points the opposite direction (to the right).

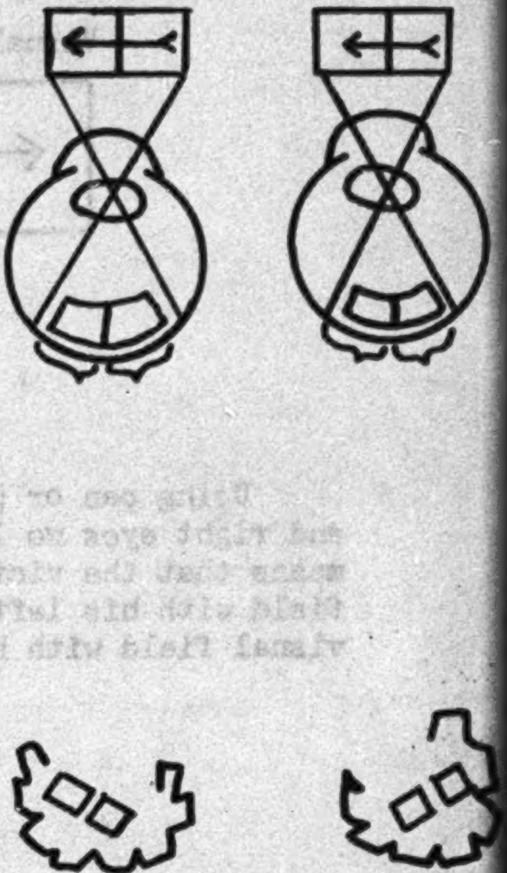
Then, draw into your diagram a dotted line representing the incision (cut) specified by the question on the reverse side of this page. Determine which neural fibers are cut by this incision and block out the signals (squares) being blocked. Block out the squares at all three levels: the brain, the eye, and the visual field. The last is your answer.

Before answering the next question of this type, draw yourself such a diagram on your work-sheet and solve the problem just as you have done here.

The optic chiasma is item 16 in Figure 3; the left optic tract is item 17 on the left.

Now place this tablet on the correct pile on your right.

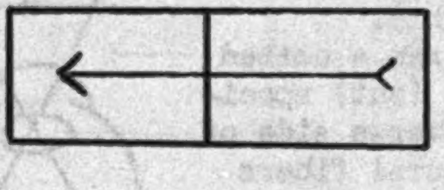




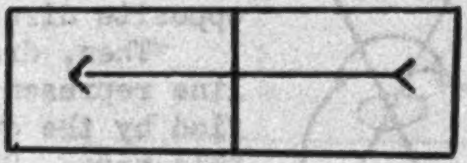
[redacted]

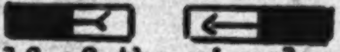
If one cut completely through the right optic nerve, what would be the extent of the blindness?

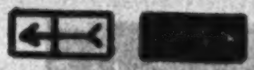
Visual field of left eye



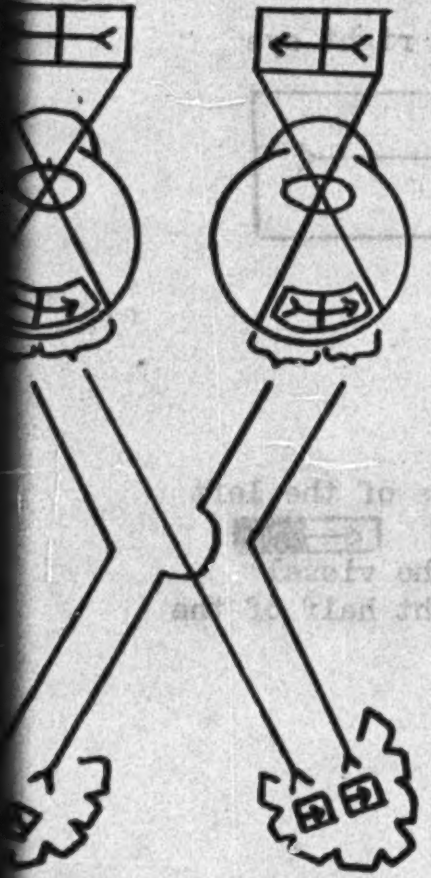
Visual field of right eye



Using pen or pencil, black out that portion of the visual fields of the left and right eyes no longer visible to the victim. For example,  means that the victim can no longer see things in the left half of the visual field with his left eye (can't see arrowhead), nor things in the right half of the visual field with his right eye (can't see arrow feathers).

Answer:  If you were correct, go to next tablet; if wrong, read below:

Using the drawing of the visual system on the left as a model, fill in the missing parts in the diagram on the right: draw in the four types of neural fibers going from the eyes to the brain, and draw in the arrows which represent the images (or pictures) being picked up by the eyes and sent, as neural signals, to the brain. Note that the lens of each eye turns the image of the arrow around; that is, the arrow being viewed in the visual field points one direction (left) while the image (or picture) of the arrow in the eyeball points the opposite direction (to the right).

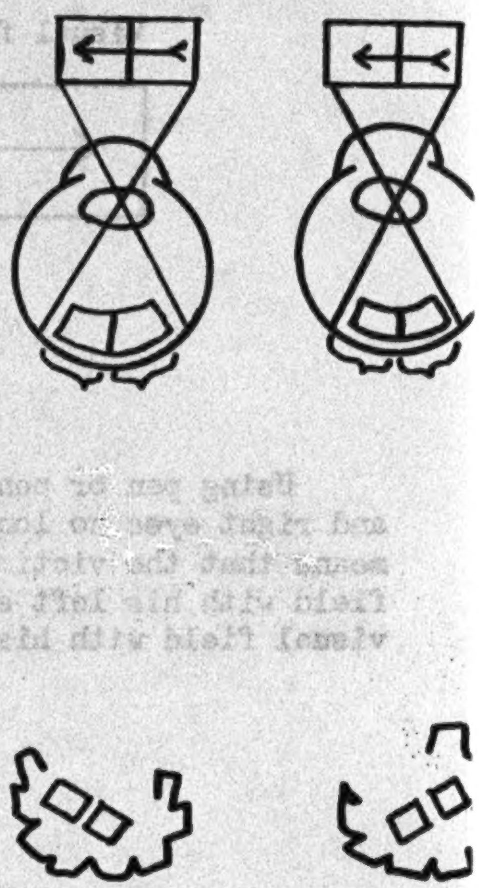


Then, draw into your diagram a dotted line representing the incision (cut) specified by the question on the reverse side of this page. Determine which neural fibers are cut by this incision and block out the signals (squares) being blocked. Block out the squares at all three levels: the brain, the eye, and the visual field. The last is your answer.

Before answering the next question of this type, draw yourself such a diagram on your work-sheet and solve the problem just as you have done here.

The right optic nerve is item 15 on the right in Figure 3.

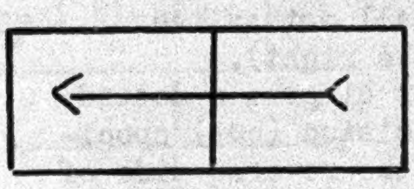
Now place this tablet on the correct pile on your right.



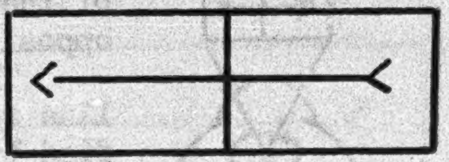
[redacted]

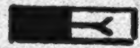
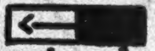
If one cut completely through the right optic tract and the left optic nerve, what would be the extent of the blindness?

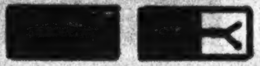
Visual field of left eye



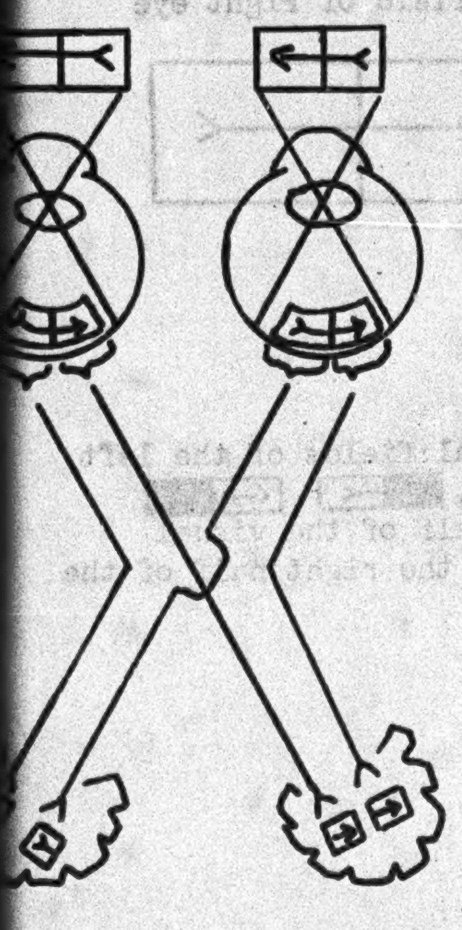
Visual field of right eye

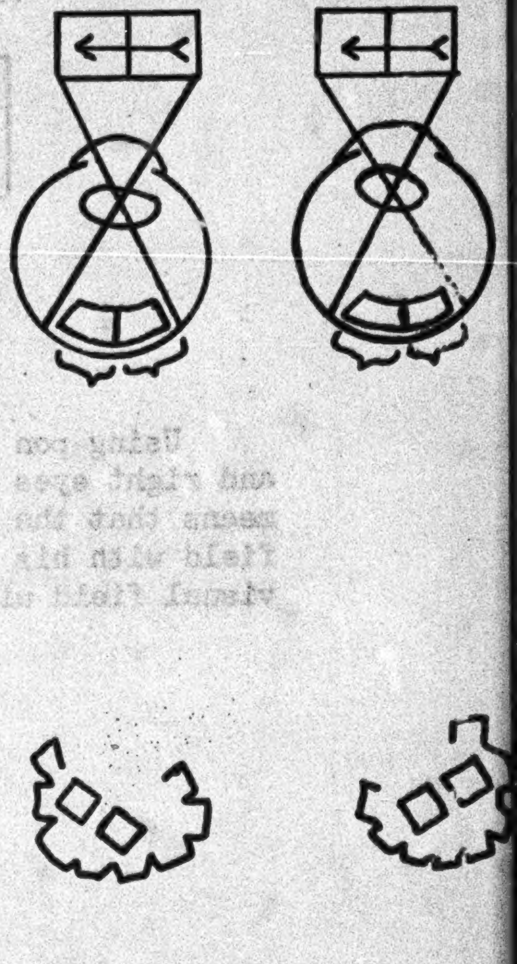


Using pen or pencil, black out that portion of the visual fields of the left and right eyes no longer visible to the victim. For example,   means that the victim can no longer see things in the left half of the visual field with his left eye (can't see arrowhead), nor things in the right half of the visual field with his right eye (can't see arrow feathers).

Answer:  If you were correct, go to next tablet; if wrong, read below:

Using the drawing of the visual system on the left as a model, fill in the missing parts in the diagram on the right: draw in the four types of neural fibers going from the eyes to the brain, and draw in the arrows which represent the images (or pictures) being picked up by the eyes and sent, as neural signals, to the brain. Note that the lens of each eye turns the image of the arrow around; that is, the arrow being viewed in the visual field points one direction (left) while the image (or picture) of the arrow in the eyeball points the opposite direction (to the right).





Then, draw into your diagram a dotted line representing the incision (cut) specified by the question on the reverse side of this page. Determine which neural fibers are cut by this incision and block out the signals (squares) being blocked. Block out the squares at all three levels: the brain, the eye, and the visual field. The last is your answer.

Before answering the next question of this type, draw yourself such a diagram on your work-sheet and solve the problem just as you have done here.

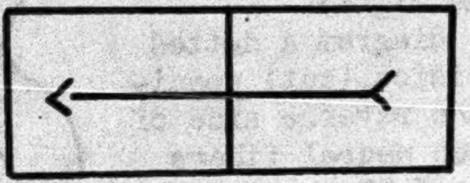
The right optic tract is item 17 on the right in Figure 3; the left optic nerve is item 15 on the left.

Now place this tablet on the correct pile on your right.

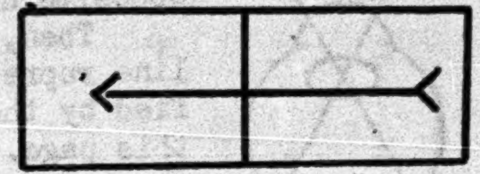
[redacted]

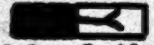
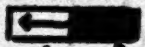
If one cut completely through the right optic tract and the right optic nerve, what would be the extent of the blindness?

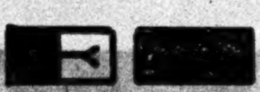
Visual field of left eye



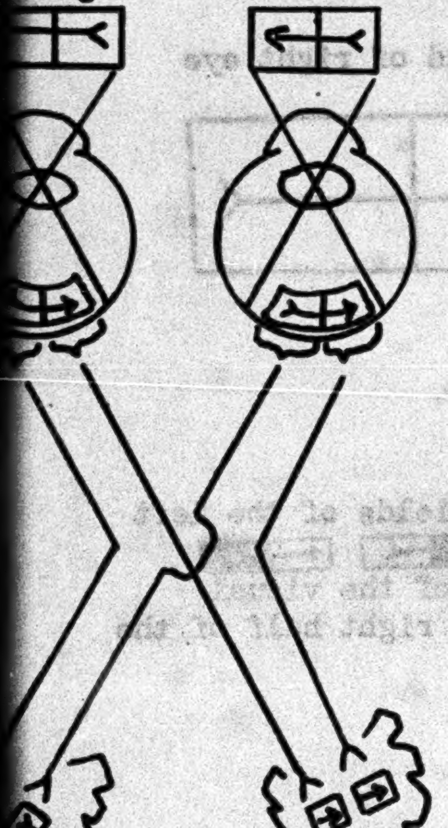
Visual field of right eye

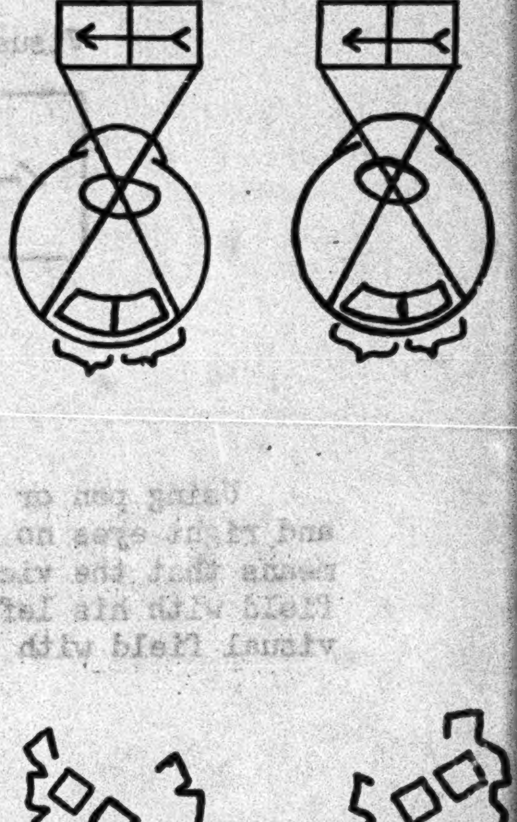


Using pen or pencil, black out that portion of the visual fields of the left and right eyes no longer visible to the victim. For example,   **means that the victim can no longer see things in the left half of the visual field with his left eye (can't see arrowhead), nor things in the right half of the visual field with his right eye (can't see arrow feathers).**

Answer:  If you were correct, go to next tablet; if wrong, read below:

Using the drawing of the visual system on the left as a model, fill in the missing parts in the diagram on the right: draw in the four types of neural fibers going from the eyes to the brain, and draw in the arrows which represent the images (or pictures) being picked up by the eyes and sent, as neural signals, to the brain. Note that the lens of each eye turns the image of the arrow around; that is, the arrow being viewed in the visual field points one direction (left) while the image (or picture) of the arrow in the eyeball points the opposite direction (to the right).





Then, draw into your diagram a dotted line representing the incision (cut) specified by the question on the reverse side of this page. Determine which neural fibers are cut by this incision and block out the signals (squares) being blocked. Block out the squares at all three levels: the brain, the eye, and the visual field. The last is your answer.

Before answering the next question of this type, draw yourself such a diagram on your work-sheet and solve the problem just as you have done here.

The right optic tract is item 17 on the right in Figure 3; the right optic nerve is item 15 on the right.

Now place this tablet on the correct pile on your right.

Light which passes through the sclerotic coat of the right eye:

a. is blocked by the choroid coat.

b. is "seen" by the left half of the retina.

c. is "seen" by the visual area of the right cerebral hemisphere.

d. is "seen" only by the visual area of the left cerebral hemisphere.

e. is focused by the lens.

f. light cannot pass through the sclerotic coat.

Answer: _____

(108c) q

Regarding, the lens:

a. approximately half the light passing through the lens of each eye is "seen" by each half of the brain.

b. the whole lens is merely a hole.

c. the lens is the transparent surface at the very front of the eye.

d. the lens controls the amount of light entering the eye.

e. b and d.

f. a and c.

Answer: _____

(109c) q

Light which passes through the sclerotic coat of the right eye:

is blocked by the choroid coat. The pigmented chorid coat, which lines the inner surface of the eyeball, is opaque and protects the retina from stray light passing through the sclerotic coat. In Figure 3, the sclerotic coat is item 9.

(108c) a

Regarding, the lens:

approximately half the light passing through the lens of each eye is "seen" by each half of the brain. The optic nerve from each eye divides into two branches with one of the two branches going to each half of the brain. In figure 3, the lens is item 5.

(109c) a

The right half of the visual field:

a. is the right half of the retina.
b. is the right half of the visual area of the brain.
c. is "seen" by the left occipital lobe.
d. is that half of the visual field "seen" by the right eye.
e. is "seen" by the right half of the brain.
f. is the medial half of the retina.

Answer: _____

Destruction of all bipolar cells would leave one:

a. totally blind in both eyes.
b. totally blind in the right half of both eyes.
c. totally blind in the left half of both eyes.
d. totally blind in the lateral half of both eyes.
e. totally blind in the medial half of both eyes.
f. partially blind in both halves of each eye.

Answer: _____

The right half of the visual field:

is "seen" by the left occipital lobe. The left halves of the eyes which "see" the right half of the common visual field send neural impulses to the left occipital lobe. In Figure 3, the visual field is item 1.

Destruction of all bipolar cells would leave one:

totally blind in both eyes. Without bipolar cells, impulses generated in the rods and cones would go nowhere. Bipolar cells transmit impulses received from the photoreceptors to the ganglion cells, the axons of which comprise the optic nerves. In Figure 3, the bipolar cells are item 11.

Light which passes through the pupil of the right eye:

a. is blocked out of the eyeball by the choroid coat.

b. is "seen" only by the left half of the retina.

c. is "seen" only by the visual area of the right cerebral hemisphere.

d. is "seen" only by the visual area of the left cerebral hemisphere.

e. is focused by the lens.

f. must first pass through the choroid.

Answer: _____

(112c) q

Without ganglion cells in the right eye one would:

a. be partially blind in the right eye.

b. be without a right optic nerve.

c. be totally blind in the right half of the visual field.

d. be totally blind in the left half of the visual field.

e. be rendered sightless in part of the left occipital lobe.

f. b and e.

Answer: _____

(113c) q

Light which passes through the pupil of the right eye:

is focused by the lens. The lens lies directly behind the pupil. In Figure 3, the pupil is item 3.

(112c) a

Without ganglion cells in the right eye one would:

both b and e: b) one would be without a right optic nerve, for the axons of the ganglion cells of the right eye comprise the right optic nerve, and e) one would be rendered sightless in the part of the left occipital lobe which normally receives impulses from the medial half of the right eye. In Figure 3, the ganglion cells are item 10.

(113c) a

Without cones, one would be:

a. totally blind in both eyes.

b. totally blind in the right half of each eye.

c. totally blind in the left half of each eye.

d. totally blind in the lateral half of each eye.

e. totally blind in the medial half of each eye.

f. color blind.

Answer: _____

(114c) q

The iris:

a. is pigmented, like the choroid coat.

b. surrounds the pupil.

c. is where the medial branch of each optic nerve crosses over to form the opposite optic tract.

d. is behind the lens.

e. a and b.

f. contains fibers projecting to the left optic tract.

Answer: _____

(115c) q

Without cones, one would be:

totally color blind. The cones are the photoreceptors responsible for daylight, color vision. However, one would retain rod vision in both halves of each eye. In Figure 3, the cones are the cone-shaped cells in item 12.

(114c) a

The iris:

both a and b: The iris is the disk of pigmented (eye-colored) tissue surrounding the pupil. In Figure 3, the iris is item 3.

(115c) a

Humor in each eye:

a. protects the retina from stray light.

b. transmits neural impulses to the ganglion cells.

c. transmits light onto the sclerotic coat.

d. transmits light onto the retina.

e. is black.

f. a and e.

Answer: _____

(116c) q

That part of the retinal image falling on the optic disk:

a. is transmitted to the right cerebral hemisphere.

b. is transmitted to the left cerebral hemisphere.

c. is transmitted to both cerebral hemispheres.

d. is transmitted to neither hemisphere.

e. the retinal image does not fall on the optic disk.

f. falls exclusively on cone receptors.

(117c) q

Humor in each eye:

transmits light onto the retina. Humor, the semifluid filling the eyeball transmits light (that is, it is transparent) onto the retina. In Figure 3, humor is item 6.

(116c) a

That part of the retinal image falling on the optic disk:

is transmitted to neither hemisphere. The optic disk, where the optic nerve leaves the eye, is without rods and cones and is, therefore, blind. In Figure 3, the optic disk is item 14.

(117c) a

Without rods, one would be:

- a. totally blind in both eyes.
- b. totally blind in the right half of each eye.
- c. totally blind in the left half of each eye.
- d. totally blind in the lateral half of each eye.
- e. totally blind in the medial half of each eye.
- f. night blind in both halves of each eye.

Answer: _____

(118c) q

Light passing through the cornea of the left eye is:

- a. negligible.
- b. "seen" by both occipital lobes of the brain.
- c. "seen" only by the left half of the brain.
- d. is blocked from the eye by the choroid coat.
- e. neural impulses (not light) pass through the cornea.
- f. a and d.

Answer: _____

(119c) q

Without rods, one would be:

night blind in both halves of each eye. That is, one could not see in dim light. One would retain the daylight, cone vision in both halves of each eye. In Figure 3, the rods are the rod-like cells in item 12.

(118c) a

Light passing through the cornea of the left eye is:

"seen" by both occipital lobes of the brain. Light passing through the cornea of the left eye falls upon a retina which in turn sends impulses to both occipital lobes of the brain, the right half to the right occipital lobe, the left half to the left occipital lobe. In Figure 3, the cornea is item 2.

(119c) a

Some neural impulses generated in the pigmented choroid of the right eye:

a. are transmitted by the right optic nerve.
b. are transmitted by the right optic tract.
c. are transmitted to the right cerebral hemisphere.
d. a, b, and c.
e. the pigmented choroid does not generate impulses.
f. are transmitted to both occipital lobes.

Answer: _____

(120c) q

The retinal image falling on the fovea:

a. is divided so that the right half of the retinal image is transmitted to the right cerebral hemisphere and the left half of the image is transmitted to the left cerebral hemisphere.
b. is divided so that the right half of the retinal image is transmitted to the left cerebral hemisphere and the left half of the retinal image is transmitted to the right cerebral hemisphere.
c. is transmitted to the cerebral hemisphere opposite the eye in question.
d. is transmitted to neither hemisphere.
e. the retinal image does not fall on the fovea.
f. stimulates only rod receptors.

Answer: _____

(121c) q

Some neural impulses generated in the pigmented choroid of the right eye:

the pigmented choroid does not generate impulses. Neural impulses are generated in the retina, not the choroid coat which protects the retina from stray light piercing the sides of the eye, that is, the sclerotic coat. In Figure 3, the pigmented choroid is item 8.

(120c) a

The retinal image falling on the fovea:

is divided so that the right half of the retinal image is transmitted to the right cerebral hemisphere and the left half of the image is transmitted to the left cerebral hemisphere. Each retina is divided into two functional halves (right and left) at the fovea so that each right half is connected to the right half of the brain and each left half is connected to the left half of the brain. The fovea contains cones not rods and is responsible for daylight, color vision. In Figure 3, the fovea is item 13.

(121c) a

The occipital lobes:

a. are physiological names for the eyes.

b. are near the forehead.

c. in each eye transmit neural impulses through the optic chiasma.

d. are the visual areas of the cerebral hemispheres.

e. are indentations on the surface of the retina.

f. each receive impulses from only one eye.

Answer: ____

(122c) q

The right optic nerve:

a. transmits impulses only to the right optic tract.

b. receives impulses from the right optic tract.

c. transmits impulses to both optic tracts.

d. receives impulses from the left optic tract.

e. transmits impulses only to the left optic tract.

f. b and d.

Answer: ____

(123c) q

The occipital lobes:

are the visual areas of the cerebral hemispheres. They are located at the back of the head. Each receives impulses from both eyes, the left lobe receiving signals from the left half of each retina and the right lobe receiving impulses from the right half of each retina. In Figure 3, the occipital lobes are items 18.

(122c) a

The right optic nerve:

transmits impulses to both optic tracts. The right optic nerve divides into two branches, the branch from the left half of the retina projecting into the left optic tract, and the branch from the right half of the retina projecting into the right optic tract. In Figure 3, the right optic nerve is item 15 on the right.

(123c) a

Without a retina:

a. no light would enter the eyeball.

b. too much light would enter the eyeball.

c. there would be no ganlion cells.

d. the visual area of the cerebral hemisphere on the same side as the eye in question would be rendered totally blind.

e. the eyeball in question would be completely empty.

f. the visual area of the cerebral hemisphere opposite the eye in question would be rendered totally blind.

Answer: _____

(124c) q

That part of the retinal image falling upon the optic chiasma:

a. is divided so that the medial half of the image goes to the right cerebral hemisphere and the lateral half of the image goes to the left cerebral hemisphere.

b. the retinal image does not fall upon the optic chiasma.

c. is transmitted to the cerebral hemisphere opposite the eye in question.

d. stimulates only cone receptors

e. is divided so that the right half of the retinal image goes to the left half of the cerebral cortex and the left half of the retinal image goes to the right cerebral hemisphere.

f. stimulates only rod receptors.

Answer: _____

(125c) q

Without a retina:

there would be no ganglion cells. The retina is comprised, basically, of three neural layers: photoreceptors, bipolar neurons, and ganglion cells. In Figure 3, the retina is item 7.

(124c) a

That part of the retinal image falling upon the optic chiasma:

the retinal image does not fall upon the optic chiasma. The optic chiasma is at the base of the brain some distance from either eye. In Figure 3, the optic chiasma is item 16.

(125c) a

The right optic tract transmits:

a. neural impulses from the whole of the right eye.
b. neural impulses from the whole of the left eye.
c. neural impulses from the right half of each eye.
d. neural impulses from the left half of each eye.
e. light within the right eye.
f. neural impulses to the left cerebral hemisphere.

Answer: ____

(126c) q

The cerebrum or cerebral cortex on the left side of the head:

a. "sees" objects in the right half of the visual field.
b. does not receive impulses from the right optic tract.
c. receives impulses from both the right and left optic nerves.
d. receives impulses from the medial half of the right eye and the lateral half of the left eye.
e. a, b, c, and d.
f. is called the left eye.

Answer: ____

(127c) q

The right optic tract transmits:

neural impulses from the right half of each eye. Nerve fibers from the medial half of each retina cross at the optic chiasma to form the optic tracts so that the right optic tract is connected to the right half of each eye. In Figure 3, the right optic tract is item 17 on the right.

(126c) a

The cerebrum on the left side of the head:

a, b, c, and d: The retinal image of an object in the right half of the visual field is projected upon the left half of each retina (or the medial half of the right eye and the lateral half of the left eye). Next, at the optic chiasma, the medial half of the right optic nerve joins the lateral half of the left optic nerve to form the left optic tract. Only the left optic tract projects to the left occipital lobe of the cerebrum. Hence, the cerebrum on the left side of the head "sees" objects in the right half of the visual field. In Figure 3, items 18 represent portions of the two halves of the cerebrum.

(127c) a

APPENDIX D

Questionnaire used in Experiment II to assess student opinion of the Incisive and Confounded Formats.

Name ____________________ Teacher _____________ Date ___________ _____

Questionnaire

Please answer these questions to the best of your ability. There are no "right" answers.

In your studying about the visual system:

1. Which type of question did you find most difficult?
    a. the type with blanks to be filled in
    b. the multiple-choice
    c. about equal

2. Which type of question was more instructive, from which did you learn more?
    a. fill in
    b. multiple-choice
    c. about equal

3. When you finished studying the first type of tablets and switched to the second, did you find that your studying the first set affected the difficulty of studying the second set?
    a. no
    b. studying the first type made it more difficult to master the second type
    c. studying the first type made it easier to master the second type

4. In learning the answers to the two types of tablets, on which type did you do most guessing initially?
    a. fill in
    b. multiple-choice
    c. about equally often for both types

APPENDIX E

Letter-Naming Time as a Function of Set Familiarity and Symbol Distinctiveness, a revised and corrected version of an interim report submitted previously.

Abstract

Two symbol-naming experiments were conducted assessing the dependence of Fitts and Switzer's set-familiarity effect upon symbol distinctiveness. Sixty college males named printed letters presented in a strobotron tachistoscope, the letter always being selected from a preannounced set of three. A voice key detected the response. Experiment I found the Fitts and Switzer finding to be a joint effect: response latency for naming the symbol B in the unfamiliar but distinctive set VBO, was intermediate to that for the familiar distinctive set, ABC, and the unfamiliar, homolographic set, PBE, the two sets used by Fitts and Switzer. Experiment II, a factorial combination of set familiarity and symbol distinctiveness revealed, moreover, that with homolographic symbols, set familiarity increases rather than decreases reaction time. The results were interpreted as consistent with an hypothesis that the set-familiarity effect relates to symbol-identification time as opposed to response identification time.

Letter-Naming Time as a Function of Set Familiarity and Symbol Distinctiveness[1]

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Fitts and Switzer (1962) have found that the response latency for naming the visual symbol B is less when it appears alternately with the symbol A and C than when it appears alternately with the symbols E and P. They attributed this effect to the differences in familiarity of the two sets of letters: A, B, and C versus P, B, and E. However, their findings might just as readily be interpreted as revealing the effect of stimulus similarity: the symbol B is graphically more distinctive in the set ABC than in the set BPE where the symbols P and E comprise mere subsets of the symbol B. Or, since the two interpretations do not appear mutually exclusive, the Fitts and Switzer finding may feflect a joint effect. In fact, the present research conducted to evaluate these alternatives, reveals that symbol distinctiveness is a necessary but insufficient condition for the emergence of a familiar-set effect.

Naming alpha-numeric characters is a perfunctory task well routinized by most literate individuals. The verbal symbol or name of each letter category is so firmly associated with its corresponding visual symbol and so fully dissociated from all others that the task involves no apparent deliberation or choice. Accordingly, it is sometimes found that the response latency for naming individual alpha-numeric symbols is independent of the number of equi-probable characters from which the symbol is selected (Brainard, Irby, Fitts, & Alluisi, 1962; Morin & Forrin, 1962; Mowbray; 1960.) However, where speed is of the essence, an experimental subject may be pressed into naming an alpha-numeric symbol before he has fully inspected it, that is, before the symbol, let alone the letter category it represents, has been thoroughly identified. In this case, the naming of the symbol becomes, clearly, a disjunctive reaction with the subject deciding with limited stimulus information which of several symbols he is viewing.

If he is to reduce his response latency in this way he must, however, possess certain prior information which allows him to "deduce" the identity of the symbol from incomplete - and otherwise indeterminate - stimulus information. Such apriori information may be provided him by an announced reduction in the number of symbols he is called to identify. For example, if he is advised that only three symbols from the 26-character alphabet are to be presented, say, A, B and C, he need only determine for each stimulus presentation whether the symbol incorporates curved or straight lines: if there are no curved lines the symbol is an "A"; if there are no straight lines it is a "C"; if there are both straight and curved lines it is a "B". The more distinctive the symbols the less stimulus information required to distinguish between them.

Providing it is sufficiently simple to employ, such a deductive technique may allow the subject to reduce his response latencies by some small but measurable amount (cf. Rappaport, 1959). Not surprisingly, several investigators (Forrin & Morin, 1966; Morin, Konick, Troxell & McPherson, 1965) have recently reported that the response latency for naming visual, alpha-numeric symbols presented individually may be reduced by limiting the number of alternative symbols presented to a total of approximately four of less. It is doubtful if a limited set-size is the only prerequisite for this effect. The symbols themselves must, presumably, differ from one another sufficiently to allow the subject to choose between them with very little stimulus information. Also, since the subject must remember the particular alpha-numeric characters which comprise the set of symbols to be named, familiarity with those symbols as a set should facilitate his use of the deductive, symbol-identification process. It is this last factor, familiarity of symbol set, to which Fitts and Switzer attribute their findings that the symbol B is named more rapidly in the set ABC than in the set BPE. However, they failed to control for the destinctiveness of the B in their two experimental sets. The experiments reported here were designed to rectify this deficiency.

In this first experiment, three sets of symbols were used, ABC, VBO, and PBE, the set VBO being as unfamiliar as BPE but including symbols as distinctive from one another as those in the familiar set ABC. It was found that the response latency for naming the symbol B was shortest for the set ABC, next shortest for the set VBO, and longest for the set BPE. In other words, both stimulus distinctiveness and set familiarity contribute to the specific findings reported by Fitts and Switzer. However, it was impossible to determine to what extent the two factors operate independently of each other since the familiar-set comparison involved only distinctive sets whereas the stimulus-similarity comparison involved only unfamiliar sets. To resolve the issue, a second experiment, a multidimensional factorial design, combined each of two levels of stimulus similarity with each of two levels of set familiarity. An interaction of these factors was expected. It was hypothesized that symbol distinctiveness would prove to be a necessary prerequisite for the familiar-set effect.

Method

Subjects. Sixty male students attending Northern Illinois University served as subjects. Twelve served in Experiment I. Forty-eight served in Experiment II.

Apparatus. The symbols to be named were black capital letters printed in the center of white paper cards, four inches square. The cards were presented in a Lafayette, Strobotron tachistoscope and were viewed from a distance of approximately twenty inches. A microphone mounted on a small boom juxtaposed the S's mouth operated an electronic voice key. Response latencies were measured with a Hunter Klockounter, accurate to .001 of a second. E activated the tachistoscope and the Klockounter simultaneously by throwing a single DPDT toggle switch; S's voice stopped both instruments simultaneously by activating the voice key.

Procedure. The Ss were run individually. Each was instructed that on each trial he was to name as rapidly as possible the letter which would become illuminated in the viewer (tachistoscope) before him. Speed rather than accuracy was stressed. If S misidentified a symbol, that symbol was presented again at the end of that particular block of trials. Nevertheless, errors were infrequent.

An experimental session was comprised of several blocks of 75 trials each. During any one block of trials only three different letters were presented. They were presented equally often and in a random order. At the beginning of each block of 75 trials, *S* was always shown the set of three letters he would be required to name.

E prefaced each trial with a signal of "ready" approximately one second before illuminating the symbol. The intertrial interval was approximately eight seconds, and the inter-block interval was of the order of several minutes.

To familiarize him with the procedure, each *S* was given nine practice trials naming the color of a small square centrally located on each of three practice cards (red, yellow, green) each presented thrice in a random order.

Experiment I. Capital letters printed in Berling Italics, 48 pts., were used (Letraset No. 317). Each *S* was administered three blocks of trials, one block with the distinctive symbols comprising the familiar set ABC, one block with the distinctive symbols comprising the unfamiliar set VBD, and one block with the homolographic symbols comprising the unfamiliar set PBE. Each of the six different permutations of these three blocks was randomly assigned to a different sixth of the *S* pool (N = 12).

Experiment II. A multidimensional design was employed. Each *S* was administered two blocks of trials, one block with a familiar set of symbols DOG (or GOD), and the other block with an unfamiliar set of symbols GCD. Half of the *S*s was given the familiar set first; half was given the unfamiliar set first. Half of each of these groups was told that the letters of the familiar set comprised the word "God"; the other half was told that the set comprised the word "dog". Half of each of these subgroups was presented relatively distinctive symbols in the form of capital letters printed in Berling Italics, 48 pt. (Letraset No. 317). The other half was presented homolographic symbols comprised basically of a circle 13/16 of an inch in diameter. The O was a full circle. The vertical upright of the symbol D was 1/4 inch in length. The gap in the symbols C and G was, in each case, 1/8 of an inch. The G included a 1/8 inch vertical line beginning at the lower edge of the gap and extending downward. The symbols were drawn in black ink with a ball-point pen. Although they could be distinguished, the symbols were not readily discriminable from one another.

Including the differences in the letters themselves, Experiment II comprised a four-factor design: Letters, Set-Familiarity, Symbol Distinctiveness, and Letter Order (God vs. dog in the familiar set). The design was mixed, with all values of the first two factors administered to each subject, and each combination of values of the last two factors administered to a different, randomly-selected quarter of the S pool ($N = 48$).

Results

Experiment I. The overall mean response latency for naming the symbol B, the one letter which appeared in all three trial blocks, use .431 sec. in set ABC, .456 sec. in set VBO and .472 sec. in set PBE. All differences among these means are significant (Sign test: $p \leq .05$).

Experiment II. Mean response latencies for naming the symbols D and G (the two letters which appeared in both trial blocks) are shown in Table 1 as a function of Symbol Distinctiveness, Set Familiarity and Letter Order (GOD vs. DOG).

Insert Table 1 about here

A four-way analysis of variance of the Ss' mean response latencies yielded four significant effects: Symbol Distinctiveness, Letter (G vs. D), a first-order interaction between Set Familiarity (GOD vs. GCD) and Letter (G vs. D), and the hypothesized interaction between Set Familiarity and Symbol Distinctiveness. The mean response latency was shorter for the distinctive symbols, .496 second, than for the homolographic symbols, .607 second, ($F = 53.93$, df = 1/44, $p < .001$. The mean response latency to the symbol D, .547 second, was shorter than the mean response latency to the symbol G, .557 second, (F = 5.17, df = 1/44, p .05). The interaction of Set Familiarity and Letter (F = 7.67, df = 1/44, p. <.01) was such that the letter G was more readily identified than the letter D in the familiar set, .549 second vs. .552 second, whereas G was less readily identified than the letter D in the unfamiliar set, .562 second vs. .545 second. The interaction of Set Familiarity with Symbol Distinctiveness (F = 7.39, df = 1/44, p <.01) was such that for distinctive symbols, mean response latency was shorter for the familiar set, .486 second, than for the unfamiliar set, .507 second, whereas for homolographic symbols the opposite was true: the mean response latency was shorter for the unfamiliar set, .599 second, than for the familiar set, .614 second.

Discussion

The present results show that although Fitts and Switzer's set-familiarity effect is genuine, the nature of the effect depends upon the distinctiveness of the symbol being named: when the symbols are distinctive, familiarity with the symbol set reduces reaction time, as reported by Fitts and Switzer; however, when the symbols are homolographic and difficult to distinguish, familiarity with the symbol set may increase reaction time.

Although the familiar-set effect depends upon symbol distinctiveness, the converse is not true. Distinctive symbols are named more rapidly than homolographic ones, irrespective of the familiarity of the set of symbols named (cf. Crossman, 1955).

The present finding of a shorter response latency for the letter D than for the letter G may be attributed to a difference in their phonetic labels. "D" is a harder phoneme better suited for detection by the voice key. Hence, this difference, also noted by Fitts and Switzer, appears trivial.

What does not appear trivial, however, is the interaction of the variables Letter and Set Familiarity, for it illustrates further the significant effect of symbol distinctiveness upon symbol identification. The letter G was more readily identified in the familiar set, GOD (of DOG), where it was the only open figure than in the unfamiliar set, GCD, where it was one of two open figures. Conversely, the letter D was more readily identified in the unfamiliar set, GCD, where it was the only closed figure than in the familiar set, GOD (or DOG), where it was one of two closed figures. Not only are the symbols of a distinctive set more rapidly identified than those of a homolographic set, but the more distinctive or unique a symbol is within its own set, the more rapidly it is identified, relative to the other members of its set.

Apparently the information prerequisite to accurate symbol naming of the type investigated here depends not so much upon the number of verbal responses (letter categories) involved, but upon the number of alternate groups of homolographic visual symbols comprising the stimuli being identified. The S̲ appears to scan mentally the letters from which he is to select his response not as individually printed symbols but as members of a hierarchy of generic sets and subsets of symbols, the subsets at each successive level of the hierarchy being composed of symbols which are relatively more homolographic than those of previous levels. It is as if he processes his stimulus information through a sequence of mental sorters with each sorter assigning the input to a progressively finer homolographic category until only one letter remains. Symbol identification time depends evidently upon the number of sorts required. Reducing the number of symbols to be identified reduces the number of sorts required, particularly when a) the symbols are distinctive from each other, and b) the symbols comprise a set easily remembered, thereby preventing irrelevant sorting. Where the symbols are very similar to each other, however, it should be time consuming to deduce, from a knowledge of the symbols to be identified, the particular sorter which would distinguish between those specific symbols. As a consequence, naming time may be lengthened as well as shortened by such a deductive process; such appeared to be the case in Experiment II. However, the present results suggest also that an individual is predisposed to use a deductive procedure disadvantageously only if the symbols being named comprise a familiar set. If the set of symbols is unfamiliar and difficult to remember, he abandons any deductive tactic as obviously impractical. Fitts and Switzer's S̲s appear to have behaved in this fashion for when they were confronted with the unfamiliar, homolographic set EBP, they responded to the symbol B as they would to any individual character of the alphabet rather than as an element in a smaller set.

That the process of symbol identification investigated here involves the scanning of homolographic symbol-categories rather than verbal response categories is evidenced further by the absence of an interaction involving the factors Letters (G vs. D) and Letter Order (G-D vs. D-G). If verbal response categories were being scanned one could expect the response latency to the symbol D to be shorter for the set D-G than for the set G-D, and the latency to the symbol G to be shorter for the set G-D than for the set D-G. However, no interaction involving these two factors proved to be statistically significant ($p \leq .05$). Of course if the scanning of response categories were exhaustive as suggested by Rappaport (1959)and Sternberg (1966) then no such interaction would be expected, but neither would one have expected the obtained interaction of Letter and Set-Familiarity. Clearly, the present results imply that symbol naming of the type investigated here involves scanning one's repertoire of visual-symbols rather than verbal responses.

Footnotes

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Table 1

Mean Response Latencies to the Symbols D and G as a Function of Stimulus Distinctiveness, Set Familiarity and Letter Order.

(Data in Seconds)

Stimulus Distinctiveness	Familiar Set		Unfamiliar Set	
	Letter G	Letter D	Letter G	Letter D
Distinctive:				
Letter Order:				
G - D	.492	.484	.518	.503
D - G	.482	.487	.503	.501
Homolographic:				
Letter Order:				
G - D	.619	.623	.618	.581
D - G	.613	.601	.607	.594

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